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PREPARED UNDER CONTRACT NO. NAS8-35969
IR&D
OTHER

PREPARED ON DOCUMENT NO. D180-27884-3

FILED UNDER W. O. 7DL85
MODEL 1-3-EH-15543

TITLE NASA/MSFC LARGE STRETCH PRESS STUDY

ORIGINAL RELEASE DATE

ISSUE NO.	TO	DATE
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ADDITIONAL LIMITATIONS IMPOSED ON THIS DOCUMENT WILL BE FOUND ON A SEPARATE LIMITATIONS SHEET.

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ABSTRACT

This document D180-27884-3 dated April 4, 1985, presents the final report for NASA Study Contract NAS8-35969.

NASA Study Contract NAS8-35969 consists of the four principal elements as outlined in the Large Stretch Press Study, Folder 1, Technical Proposal D180-27884-1, submitted by Boeing Aerospace Company to the National Aeronautics and Space Administration, George C. Marshall Space Flight Center on November 7, 1983.

Document D180-27884-3 has been prepared in five separate sections to enable elemental distribution.

1.0 INTRODUCTION AND OVERVIEW

2.1 PHASE I TASK A - Cost Study

2.2 PHASE I TASK B - User Survey

2.3 PHASE II TASK A - Site Selection Trade Study

2.4 PHASE II TASK B - Press Design Requirements and Procurement Specification

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NASA LARGE STRETCH PRESS STUDY
REFERENCE NASA CONTRACT NAS8-35969

1.0 INTRODUCTION

The purpose of this study was to:

- A. Assess and document the advantages/disadvantages of a government agency investment in a large stretch form press on the order of 5000 tons capacity (per jaw)
- B. Develop a procurement specification for the press.
- C. Provide trade study data that will permit an optimum site location.

1.1 STUDY TASKS

Tasks were separated into four major elements:

- A. **Cost Study:** Develop cost data for projected stretch form process excluding material costs, shipping costs and stretch press capitalization/depreciation costs. Evaluate cost savings from producing larger External Tank (ET) gore segments (up to 150% in width). Parts drawings and current cost data will be made available to the successful bidder.
- B. **User Survey:** Contact specific design/manufacturing organizations of various government (and commercial/industrial) agencies and identify those agencies which have requirements (or potential) for a large stretch press. Determine current and future needs assuming a large stretch press was available.
- C. **Site Selection:** Explore the feasibility of a government owned, contractor operated stretch forming facility conveniently located nearby applicable ancillary equipment. Provide two options: (1) to support existing Space Shuttle External Tank (ET) project and (2) optimum site for all NASA/government

programs (both options may be at the same site). Support recommendations with cost/trade study data to substantiate recommendations.

- D. Press Design/Procurement Specification: Prepare a specification for the design/procurement, installation, performance and inspection of a stretch press with a 5000 ton (per jaw) minimum capacity. Press may be of modular design with initially lower capacity and capability but must be capable of achieving the target 10000 ton ram force with subsequent modular additions.

See appendix I for detailed scope of work.

1.2 PERIOD OF PERFORMANCE

July 1984 to April 1985.

1.3 LARGE STRETCH PRESS DEFINITION

The customers requirements for a large stretch press were established to be for a 10,000 ton longitudinal and transverse type press with individual jaw force of 5000 tons, 1½" opening and a die table capable of 10,000 tons ram force. The Press is to be capable of processing aluminum alloy 2219-T37 plate 1.00" thick x 210" wide x 480" long.

1.4 PARTS PROCESSING INFORMATION

Existing external tank (ET) parts recommended for consideration are the tank gores and dome segments which are currently stretch formed from 2219-T37 aluminum alloy to contour and extensively chem-milled prior to heat treating to a T87 condition and final machine. The dome caps were also recommended for consideration. They are spun formed and machined; they are not stretch formed. All detail

parts fabrication is accomplished in the Los Angeles, CA area. These details are then shipped to the NASA-Michoud New Orleans, LA facility for subassembly and final assembly.

This portion of the study evaluates the overall feasibility of the use of a large stretch press to fabricate larger ET components that will be presculptured (pre-machined) prior to stretch forming to reduce detail fabrication costs, assembly costs, eliminate chemical milling, and reduce assembly costs.

1.5 EXTERNAL TANK PARTS CANDIDATES

There are four major ET subassembly components areas which could potentially result in reduced unit part costs and welding assembly and inspection costs by increasing individual part sizes. The four major areas are as follows:

<u>Nomenclature</u>	<u>Number Segments</u>	
	<u>Existing</u>	<u>Proposed</u>
LO ₂ Aft ogive	12	8
LO ₂ Aft bulkhead	12	8
LH ₂ Aft bulkhead	12	8
LH ₂ forward bulkhead	12	8

Existing ET component designs for these major subassemblies will require redesign for (1) the larger size of these components and (2) for premachining (presculpturing) and stretch forming as the manufacturing process to replace the existing chemical milling design.

The economical offset to the requirement for redesign of these components is that, per NASA/MSFC the existing heat treat fixtures and assembly tools can accommodate these larger size components without any major redesign or rework. In addition, the amount of reduced weld joint assembly and inspection labor should result from using larger parts.

1.6 OTHER STUDY OBSERVATIONS

In addition to the baseline study contract some additional observations were requested by NASA/MSFC in relation to (a) the effect of increased environmental controls on the chemical milling industry and (b) optional manufacturing process/design concepts - for E.T. type structures.

A. Effect of increased environmental controls on the chemical milling industry.

The spent aluminum solutions consist primarily of sodium carbonate, sodium aluminate, sodium hydroxide, sodium sulfide and triethanolamine. None of these are particularly toxic. The spent solution also contains smaller amounts of copper sulfide, zinc sulfide and traces of chromium and lead. These heavy metals preclude sewer disposal.

A process exists to regenerate aluminum chem-milling solutions, but because of inexpensive disposal methods in the USA, only Japan is using the process at the present time. Boeing Wichita has treated spent aluminum chem-mill solutions in the past, and expects to implement the Japanese method in their facility next year at a cost of 1.6 million.

Spent chem-mill solution is a priority waste because EPA wants to restrict landfill disposal of liquids. In the future, chem-mill shops may need to centrifuge or dewater the waste some other way prior to landfill disposal of sludge. The technology exists to recycle the spent solution continuously with less waste generation as mentioned above. The chem-mill industry is not in danger of a shut-down due to anticipated EPA requirements.

B. Optimal manufacturing process/design concepts for E.T. type structures.

1. Rationale for Alternate Design Concept Selection

Several very basic considerations of relationships of the E.T. tank detailed structural design to resultant cost and weight savings should be evaluated.

The most significant consideration in terms of determining the size or load capability of the stretch press required to fabricate stretch formed parts is the area of part cross section normal to the direction of stretching. As a general rule the cross section area normal to the direction of stretching should be essentially constant along the length of the part in order to provide uniform stretching. These considerations also lead to assuming at least a partial pre-machining of the parts before stretch forming would be beneficial.

A feature which significantly affects chemical milling fabrication costs is the amount of detailed thickness mapping and the number of successive chem-milling operations required to produce a part within dimensional tolerances. This consideration provides incentive for finding ways to reduce the initial

thickness of the part and minimize the amount of stretching and resultant differential thinning in the part.

In addition a reduction in the number of weld lands by using larger width segments could be used to offset a weight increase that might result from increasing tolerances on thicknesses by using pre-machining in preference to extensive chemical milling.

2. Discussion of Study Candidates

a. Reduced number of larger gores.

This concept will make excellent use of increased stretch forming capabilities and will reduce the cost of joining the gores in proportion to the number of gores eliminated. It will also make corresponding reductions in resultant weight of weld lands without involving a basic tooling concept change. This should be a low technical risk choice and require a minimum of engineering/analysis support.

b. Stretch form pre-machined gores.

This is a particularly appealing approach which would result in essentially no change in the final assembly tools and should offer added advantages if employed with the existing longitudinal design or for futures a transverse gore design concept. Specific advantages are reduced stretch forming loads and the elimination of chem milling or a reduction of chem milling to further reduce costs and reduce work in process flow times.

3. Expected Preliminary Results and Candidate Selection for Further Study

It is anticipated that optional study candidates could be found that would be most desirable for different structural subassemblies of the E.T. and that combinations of the concepts studied will be most advantageous. Forming of those gore segments with lands suitable for welding in the heavy bosses may also prove to be advantageous. A separate research and development study could be beneficial to the existing E.T. program and future programs.

APPENDIX A

**LARGE STRETCH PRESS STUDY
NASA STUDY CONTRACT NAS8-35969**

COST STUDY

PHASE I TASK A

APRIL 1, 1985

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2.1 PART COST COMPARISONS

PHASE I TASK A

2.1.0 OVERVIEW

The Boeing Technical Proposal Response document D180-27884-1 (p. 54) requested that "detail manufacturing plans (shop orders) for gores, ogives, and domes, and related cost data, are required for the successful performance of this program." After contract award current customer (full-up) dollar cost data was received for the cost study task, which while not conducive to detail manufacturing process cost analysis was used for comparative purposes. See figure 2.1-1 for cost comparison problems using gross dollar data which due to its subcontractor location, local labor rate and charging practice creates variations that are not directly comparative. As a preferred option, cost data, was requested in terms of actual manhours or labor standard hours as related to the manufacturing processes for any one of a number of potential candidate parts for stretch forming. This information was also not available and as a result two different approaches were made to simulate the current parts costs.

(A.) Boeing type II labor standards data based on part cost by size and complexity was simulated.

(B.) A Boeing estimate for manhour data was made for three select candidate parts.

Our approaches to simulate parts costs by either method did clearly indicate a cost advantage by changing the existing manufacturing process from chemical milling to skin milling and from raw material pre-forming to precision stretch forming of premachined (presculptured) panels.

Cost comparison problems		
Cost category	Contractor facility	Government facility
Direct cost		
•Labor cost	Location sensitive	Location sensitive
Overhead cost		
•Operating facility maintenance	Expense	GFP or ?
•Capital equipment	Expense	GFP or ?
•Facilities and buildings	Expense	GFP or ?
Raw materials		
•Plate	GFP	GFP

Figure 2.1-1 Dollar Data Cost Comparison Problems

It must be emphasized that while our simulations did indicate a cost savings on an individual parts basis they were inhibited by the unavailability of proprietary manufacturing process plans, actual labor manhours, or labor standards data. In addition there are some other major cost savings factors to be considered. Of major cost savings significance would have been the availability of External Tank (ET) final assembly information as the use of larger components can reduce the final assembly, parts handling, setup, welding, and inspection costs. This data should be evaluated by NASA/MSFC as it could be a significant savings. The scope of this cost study was also limited, in that it did not encompass any long range futures provisioning for design growth of a new generation larger diameter external tank, Space Station, or other large space vehicles requirements for ogival segments. The design growth potential for larger width gore segments and reduced assembly costs and flow times are additional justification for a large stretch press as technologically there is no other process available for the economical fabrication of larger parts.

2.1.1 BOEING SIMULATED TYPE II LABOR STANDARDS ANALYSIS

Summary dollar cost data provided by the customer was used as a guideline to determine what were the cost drivers to the current ET detail parts. The dome-cap spinning/premachining, and the extensive chemical milling for the gore segments are the cost drivers for these detail components. Boeing proceeded with the development of baseline cost data using current ET parts drawings and type II labor standards as defined in Military Standard (MIL-STD) 1567.

MIL-STD-1567 establishes certain requirements which must be met for a contractor's work measurement system to be considered acceptable. These requirements are intended to permit maximum contractor flexibility in the application of

the standard rather than providing rigid methodology by which work measurement should be accomplished. The contractor's work measurement program must be documented and include the elements described as follows:

- a. work measurement plan and supporting procedures
- b. clear designation of the organization and personnel responsible for executing the system
- c. plan to establish and maintain engineered labor standards of a known accuracy
- d. plan of continued improved work methods in connection with the established labor standards
- e. plan for the use of labor standards as an input to budgeting, estimating, production, planning, and touch labor performance evaluation

The work measurement system uses engineered labor standards in most phases of manufacturing operation. A labor standard describes the time allowed for a normally skilled operator following a prescribed method, working at a normal all-day level of effort, to complete a defined task with acceptable quality. An engineered standard is one established using a recognized technique, such as time study, work sampling, standard data, or a predetermined time system, to derive at least 90 percent of the total time associated with the labor effort covered by the standard.

In order to confirm the conclusion drawn from the NASA full up dollar cost data, Boeing labor standards data which is compliant with MIL-STD 1567 was used for comparison of processing by stretch forming, and chemical milling against processing by N/C skin-milling and then/stretch forming parts. A comparison was

made between each of the two processes based on part standard by size, and part standard by complexity. Setup and run times were analyzed separately for each process. Data is in labor standard minutes for aluminum sheet (plate) material.

As a general overview labor standards in minutes for setup of a stretch formed part of a given size can increase up to 300% depending on the complexity of the part. Complexity is based in terms of the number of separate floor-to-floor operations to complete the process (punch, drill, saw, trim, etc.). The run times for a stretch formed part remain relatively constant. Labor standard for chemical milled part setup time of a given size part can however increase up to 200% and depending on the complexity of the part run times can increase over 300%.

The existing design of the ET parts evaluated, when combined with the limited commonality of parts within most major or structural areas, prohibits economical lot size manufacture by any other process other than extremely time extensive chem milling.

In the proposed process (N/C skin mill and precision stretch forming), NC skin milling (pre machining) set up costs are relatively insensitive to the size or complexity of the part and the run times are relatively constant. The set up times for stretch forming a premachined E.T. part are however assumed to be more complex and as a result they are over 30% longer than those for forming unmachined plate as was done (105 min. v/s 134 min.) but the run times are the same.

Of significance is the fact that when using a large aircraft skin mill, multiple parts can be produced with a one time setup cost and a multiple run time based on the quantity of the same parts on the skin mill bed. In the case of the LOX Forward

Ogive Gore, at least 6 ogives can be machined in sequence and the average part cost is 555 minutes (setup 149 minutes + 6 parts x 530 minutes each (3180) = 555 minutes). The same productivity efficiencies are applicable for a large production stretch press with finite yield point controls and air bearing die conversion systems which enhance lot size production. See Figure 2.1.1-1, Summary Comparison (Labor Standards) for details.

Labor standards per se indicate that there is a cost savings in changing the fabrication process from chemical milling to premachining by large aircraft skin mills. There are however additional savings of work in process flow times that provide further justification for the procurement of a large stretch press.

From a technology standpoint the only economical process for the precision forming of large presculptured E.T. plate components is a large modern production stretch press. Only the latest design presses are capable if the finite yield point control and low end tonnage control that is required for large pre-machined, high value, parts. In addition only the latest design presses can accommodate air bearing die change over systems which increase productivity. There are only two large production stretch presses in the United States that are in the 1,500 ton (750 ton/jaw) range. Neither of these presses are of either adequate size or capacity to support the existing or proposed E.T. rate requirements nor the anticipated increase in plate width.

Per our user survey (Phase I, Task B) there is positive industrial interest and application for a large stretch press in either the 5,000 or 10,000 ton range as a national asset.

LABOR STANDARDS SUMMARY (MINUTES) FORWARD LOX OGIVE EXAMPLE

OPERATION	SIZE	TIME/MINUTES	OPERATION	SIZE	TIME/MINUTES
<u>EXISTING METHOD</u>		<u>SETUP**</u> <u>RUN***</u> <u>CUM</u>	<u>PROPOSED METHOD</u>		<u>SETUP**</u> <u>RUN***</u> <u>CUM</u>
STRETCH FORM			N/C SKIN MILL		
WTGC* AAR	XX-LARGE	105 142 (247)	WTGC* DAEP	LARGE (1)	149 3180(2) (555 AVG)
			LOT SIZE 6 PARTS		
CHEM MILL			STRETCH FORM		
WTGC* AAC	XX-LARGE	298 629 (927)	WTGC* AAR	XX-LARGE	134 143 (277)
		TOTAL 1174			TOTAL 832

* Work Type Group Code

** Setup Time (Distributed Cost)

*** Run Time (Direct Cost)

SUMMARY

- o The changing of process from the existing method to the proposed method reduces setup and run time by 40% on each part.
- o Only a new design, large production stretch press is capable of forming large precision premachined parts.

(1) Labor standards size criteria for machined skins uses different size elements than for Stretch Form or Chem-Mill.

(2) The run time for one part is 530 min.x6 parts= 3180 min.

Figure 2.1.1-1 Summary Comparison (Labor Standards)

2.1.2 SIMULATED PARTS COST ANALYSIS: CHEM MILL VERSUS SKIN MILL

A comparison of selective high cost E.T. parts using a simulated parts cost analysis shows skin milling to be significantly less expensive than the costs for chemical milling. An estimate was made for the LH₂ aft dome cap, the LOX aft dome gore, and the LH₂ forward dome gore. It appears that the dome caps which are manufactured by a combination of machining and chemical milling would cost significantly less if they were premachined and then stretch formed presuming there are no technology problems with this process.

The detail estimates are made based on the following ground rules.

- (A.) All parts are machined in a flat condition whether chemical milled or skin milled (premachined).
- (B.) Current 2219T37 raw material is baseline.
- (C.) There are no significant metal forming technology problems involved in the stretch forming of premachined components.

Parametric data was developed from Boeing estimating data and is related to the estimated square feet of the part requiring a given operation. This data is then summarized to the estimated total hours and a hypothetical constant dollar rate per hour is used to develop an estimated part cost.

Figure 2.1.2-1 through 2.1.2-3 were developed using labor standards and run times for large aircraft skin mills which could be used for premachining the candidate parts in lieu of the existing chemical milling process for metal removal.

The increase of the width of the existing gore segments (i.e., from 12 to 8) does not appear to result in any significant individual part cost reduction based on our simulated cost analysis however the reduced assembly costs appear to be significant.

SKIN MILL
 LH2 CAP AFT DOME
 809-1459-0991

SET UP RUN

INSPECT AND IDENTIFY		.675
MILL EDGE TO CLEAN UP	1.50	.250
MILL TAPER SIDE ONE 156 x 156 / 100 / 60 = 4.056	1.50	4.056
MILL POCKETS WITH 5. OR (2) PLACES 144 x 144 / 50 / 60 = 6.912	.75	6.912
MILL STEP WITH 6.12R (2)	.50	.600
NOTE: 56.0 & 45.0 DIA HOLES MACHINED AFTER FORMING		
DEBURR		2.405
INSPECT HANDLING TIME		.165 .200
CLEAN		.338
WRAP & IDENTIFY		.150
TOTAL SET UP DIVIDE BY 6 PARTS PER LOT	4.25	.708
TOTAL MANHOURS		16.454
RATE PER HOUR		\$ 200.00
TOTAL DOLLARS		\$ 3,291.80

2.1.2-1 Skin Mill LH₂ Forward Dome Gore Estimate

SKIN MILL
 LOX AFT DOME
 809-1266-0001

SET UP RUN

INSPECT AND IDENTIFY		.675
MILL EDGE TO CLEAN UP	1.50	.250
MILL TAPER SIDE ONE 96 x 217 / 100 / 60 = 3.472	1.50	3.472
MILL 9 POCKETS AT 90% OF SIDE	.50	3.472
MILL TAPER OPPOSITE SIDE	1.50	3.472
MILL 9 POCKETS AT 90% OF SIDE	.50	3.125
DEBURR		.723
INSPECT		.594
HANDLING TIME		.200
CLEAN		.289
WRAP & IDENTIFY		.150
TOTAL SET UP DIVIDE BY 6 PARTS PER LOT	5.50	.916
TOTAL MANHOURS		16.808
RATE PER HOUR		\$ 200.00
TOTAL DOLLARS		\$ 3,361.60

2.1.2-2 Skin Mill Lox Aft Dome Gore Estimate

SKIN MILL
 LH2 FWD DOME GORE
 809-1416-0993

SET UP RUN

INSPECT AND IDENTIFY		.675
MILL EDGE TO CLEAN UP	1.50	.250
MILL TAPER SIDE ONE 96 x 217 / 100 / 60 = 3.472	1.50	3.472
MILL 2 POCKETS AT 95% OF SIDE.	.50	3.298
MILL TAPER OPPOSITE SIDE AND 2 POCKETS 3.472 +3.298	2.00	6.770
DEBURR		.963
INSPECT HANDLING TIME		.132 .200
CLEAN		.385
WRAP & IDENTIFY		.150
TOTAL SET UP DIVIDE BY 6 PARTS PER LOT	5.50	.916
TOTAL MANHOURS		17.028
RATE PER HOUR		\$ 200.00
TOTAL DOLLARS		\$ 3,405.60

2.1.2-3 Skin Mill LH2 Aft Dome Cap Estimate

Based on the two separate efforts by Boeing to simulate ET parts cost data there is a clear indication based on the data simulation that there is a significant individual parts cost advantage to justify the change of existing processes. See figure 2.1.2-4 for a comparison of chemical milling current program costs vs N/C skin milling parametric costs for selected components. The requirement for a large stretch press is dictated (1) by the change of manufacturing process from chemical milling to skin milling and (2) the technological requirement for a large stretch press to form these existing E.T. precision parts which does not exist in industry today. In addition any future increase in plate size edicts a change in process due to the limitations on highway transportation systems (see Phase II Task A for substantiating analysis).

Based on parametric cost estimates the cost savings for the change of manufacturing process which dictates the use of a large stretch press would pay the total cost for a 5000 ton large stretch press in less than 100 external tank units.

There are, however, other program cost and schedule considerations which, while outside the scope of this cost study, are significant for further cost reductions and productivity improvements.

2.1.3 ADDITIONAL COST STUDY CONSIDERATIONS

- A. The increase of existing ET gore segment size while requiring a redesign of the parts would result in at least a 30% reduction of final assembly handling and setup costs, welding costs, and inspection costs.
- B. All component redesigns are structurally localized into select major assembly structural areas and would not affect ET final assembly.
- C. The existing NASA tooling can accommodate larger gore segments without major rework.

<u>E.T. PART</u>	<u>PROCESS</u>	<u>CURRENT</u>		<u>DELTA</u>	
		<u>DOLLAR COST</u>	<u>PARAMETRIC COST ESTIMATE</u>	<u>CURRENT DOLLAR VS. PARAMETRIC</u>	
Lox Aft Dome Gore	Chem Mill	\$6319			
Lox Fwd. Dome Gore	N/C Skin Mill	---	\$3362	(-) \$2957	V/S Chem Mill
	Chem Mill	\$5707			
LH ₂ Cap Aft Dome	N/C Skin Mill	---	\$3406	(-) \$2301	V/S Chem Mill
	Chem Mill	\$7000			
	N/C Skin Mill	---	\$3292	(-) \$3708	V/S Chem Mill

- o Based on parametric estimates the costs of N/C skin milling (with the exception of the LOX forward dome) are about \$3000 less per part than chemical milling.
- o Based on existing part size for the total of 59 E.T. parts evaluated (3 dome caps, 8 Lox fwd. ogives, 12 Lox aft ogives, 36 dome/bulkhead ogives) savings are \$164,000 per E.T. unit or \$16.4 million for 100 units.
- o The estimated costs for a 5000 ton stretch press (\$12 to 15M) would result in a productivity payback in less than 5 years @ 24/year E.T. rate.
- o By using a large stretch press in conjunction with N/C skin milling the program schedule for these parts could be reduced by 50%. The cost avoidance in near term dollars is significant.

Figure 2.1.2-4 Comparative Analysis Dollar Actuals vs Simulated Analysis Cost

- D. The major advantage of skin milling (premachining) and large stretch press forming is the ability of these combined processes to drastically reduce the existing lengthy process flow times currently required for chemical milling.
- E. Premachining and stretch forming enables larger lot size production which permits reduced setup costs.
- F. Premachining and stretch forming permits rate acceleration and/or surge capability that the existing chemical milling process cannot provide.
- G. Any future design growth for larger external tanks or other larger space vehicles cannot be accommodated without change in the manufacturing process and a large stretch press with waterway access.

APPENDIX B

**LARGE STRETCH PRESS STUDY
NASA STUDY CONTRACT NAS8-35969**

USER SURVEY

PHASE I TASK B

APRIL 1, 1985

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USER SURVEY
PHASE I TASK B

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USER SURVEY
PHASE I TASK B

2.2.0 SURVEY FORMAT

The survey format was designed to encompass all of the large stretch press study areas in relation to:

- A. Baseline external tank (ET) requirements (Exhibit A--NASA Scope of Work).
- B. ET proposed requirements for this capability.
- C. Other potential product line requirements.
- D. Location options.
- E. Ownership/operational preference (government owned/contractor operated, etc.).
- F. Other size and material type requirements.
- G. Other potential production requirements (rate, lot size, etc.).
- H. Estimate of parts requirements in five-year increments.
- I. Press specification options - extrusion jaws; bed, die, jaw, etc. size requirements.
- J. Other comments.

The survey format as developed was pre-tested by coordination, in-house with applicable technical personnel, and then coordinated with the three prime U.S. stretch press equipment manufacturers prior to distribution. A copy of the survey form is in Appendix 2.B-1.

2.2.1 SURVEY CONTACTS

The development of the survey contact list required an extensive effort. Existing contacts within the Aerospace Industries Association were utilized in a selective basis. Seventeen surveys were sent to members of this group.

Government agency listings were prepared on the basis of auditing the Federal Register and listings provided by the Boeing Washington, DC office. These listings were supplemented by other government agencies which had either conducted or participated in similar surveys. In some cases, multiple surveys were sent to a given agency to insure coverage. Twenty-nine surveys were sent to government agencies.

Commercial/industrial companies involved in industrial, construction, shipbuilding, power generation, nuclear construction, and external tank component fabrication were developed through research of periodicals, etc. Seventeen surveys were sent to these companies.

In addition, each equipment manufacturer was sent extra copies of the survey for distribution to any of their existing or potential U.S. customers not previously covered by the Boeing survey.

2.2.2 SURVEY DISTRIBUTION

Of the 63 survey forms sent out, only one was returned due to an address error. Survey distribution was made incrementally starting on July 26, 1984 through August 29, 1984, with responses being received from August 22, 1984 through October 10, 1984. A copy of the survey mail listing is in Appendix 2.B-2.

Per NASA/MSFC request on November 15, 1984, a follow-on survey was conducted of 28 addressees that did not respond to the initial survey. This resurvey was distributed on December 7, 1984 with responses received by January 11, 1985.

2.2.3 SURVEY RESULTS

The survey results are summarized in **FIGURE 2.4-1**, with a detailed analysis of the government agency responses in **FIGURE 2.4-2**.

Of the 63 survey forms mailed, over 59 percent responded. Of those responding, 14 percent had potential requirements which could utilize a large stretch press based on the survey questionnaire criteria.

Of those that responded with potential requirements only one had a requirement for a 10,000 ton (5,000 ton per jaw) stretch press. The predominate responses were for a press no larger than 5,000 tons (2,500 tons per jaw). The response data has been summarized in **FIGURE 2.4-3**. This data has been included in our other study tasks (Cost Analysis, Site Analysis and Equipment Specification) as additive to the baseline external tank requirements for other potential product line applications.

Large Stretch Press Study Phase I, Task B

Summary response

Agency and industry	Survey submittal and response			Interest		Comments	
	Submitted	Percent	Received	Percent	Yes		No
Aluminum suppliers	3		3			3	No requirement; submitted plate data
Equipment manufacturers	4		3		3		Two supported study
Subtotal (no count)	7		6		3	3	
Government agencies	29	46 ^a	19	66 ^b	1	18	
Select AIA members	17	27 ^a	12	71 ^b	2	10	Two "no requirement," but supplied futures data
Other industrial (ship-building, nuclear, construction)	17	27 ^a	6	35 ^b	2	4	
Total	63		37	59 ^a	5 14 ^a	32 86 ^a	

^aTotal survey, %

^bAgency and category response, %

FIGURE 2.4-1

Large Stretch Press Study Phase I, Task B

Government response

Government agency	Survey submittal and response			Interest		Comment
	Submitted	Percent	Received	Percent	Yes	
NASA	1		1		1	
U.S. Air Force—Pentagon	1		—			—
U.S. Air Force—Wright Patterson AFB	3		1		1	1
U.S. Army—Pentagon	1		—			
U.S. Army—Rock Island, etc.	5		5		1	5
U.S. Navy	3		1		1	1
Department of Defense—Pentagon	2		1		1	1
Department of Commerce	4		1		1	1
DOT—U.S. Coast Guard	1		1		1	1
DOT—FAA (aviation standards)	1		1		1	1
DOT—Federal Highway Administration	1		1		1	1
DOT—Commerce and Space Transportation	1		1		1	1
Department of Energy	4		4		4	4
Department of Agriculture	1		1		1	1
Total	29	46^a	19	66^b	1	18

^aTotal survey, %

^bGovernment agency response, %

FIGURE 2.4-2

Responsee	Category	Size and material for use over and above baseline ET requirements		Other potential requirements size and (year)	Number parts per year and type product	Number parts per year in 5-year increments (1980-85, etc.)	Other press capability requirements	Maximum bed length, in	Maximum die length, in	Maximum jaw width, in	Maximum curve width, in	Most advantageous location	Site operation		Comments			
		Material type	Temper										Contractor-owned facility - contractually operated press	Contractor-owned facility - government press		Consortium		
A	Aircraft industry	Aluminum 7075 Aluminum-lithium Titanium 15-3	0 to T6 -	<ul style="list-style-type: none"> Aircraft skins 96 x 400 (1990) Aircraft chords (1986) 	<ul style="list-style-type: none"> 188 parts per year Continuous production 14 per month 	-	Yes-with ability to form over bed 15 ft vertically	940	400	120	-	<ul style="list-style-type: none"> Los Angeles County, California 	-	<ul style="list-style-type: none"> Contractor-owned facility - government press 	<ul style="list-style-type: none"> Consortium 	If a larger stretch press is available, larger components will be designed to utilize the capability		
B	Aircraft industry	7075W 2024W 2024	HT to T6 HT to T42 T3	-	<ul style="list-style-type: none"> 160 parts per year Lot size 10 Continuous, 16 month 	<ul style="list-style-type: none"> (1990 year) 200 7075 extrusion: 200 2024 extrusion: 200 2024-T3 plate: 400 (1995 year) Same as above (2000 year) Same as above, but double rate per year 	Yes-need for sheet and plate, as well as extrusions	400	480	240	120	<ul style="list-style-type: none"> Seattle, Washington 	-	-	-	-	-	
C	Aircraft industry	No requirement for 5000-ton or larger size press for known programs. In future, need to look at Z219-T37 aluminum plate and room-temperature-formable titanium.		-	-	-	Yes-need extrusion adapter for up to 24-ft extrusions	380	288	188	72	<ul style="list-style-type: none"> St. Louis, Missouri New Orleans, Louisiana Los Angeles, California 	-	-	-	-	-	A 5000-ton press with proper controls has potential to stretch a wide variety of shapes from 15V-3A1-3CR-35N titanium sheet and plate. This material is room-temperature-formable to limits beyond typical aluminum alloys. It is heat treatable in same temperature range as aluminum and is readily weldable. A 5000-ton press with capability for 15-3-3-3 up to 0.500-width x 144-in length.
D	Commercial	2219 aluminum alloy 316 CRES 2024 aluminum alloy 2024 aluminum alloy	T37 - T4 -	<ul style="list-style-type: none"> ET ogive gores and dome gores Large pressure vessel components Airframe components 	<ul style="list-style-type: none"> 150 to 200 parts per year Lot size 25 to 50 pieces 	<ul style="list-style-type: none"> (1990 year) 200 to 300 (1995 year) same (2000 year) same (2005 year) same 	Some extrusions would require jaw change-ability to change jaws useful but not necessary	480	300 long x 180 wide	200	Jaw chord height 30	<ul style="list-style-type: none"> Los Angeles, California 	-	<ul style="list-style-type: none"> Contractor-owned facility - government press 	-	-	This type of press is not suitable for forming (ET) dome caps.	
E	Government research	2219	T37	<ul style="list-style-type: none"> T-sections, box beams, and I-beams Space Station 	-	-	-	-	300 long x 200 wide	200	50	<ul style="list-style-type: none"> Huntsville, Alabama 	-	-	-	-	-	Maximum size; requires 10,000 ton
F	Commercial	Mild plate steel	-	<ul style="list-style-type: none"> Ship bows, bow plates, stern plates, and some frames 	<ul style="list-style-type: none"> Unknown. If a ship contract of sufficient quantity were received and if the government would pay for tooling, it would be feasible. 	-	Some potential extrusion applications	620	540 long x 144 wide	-	Curved jaw chord height 120	<ul style="list-style-type: none"> San Diego, California Los Angeles County, California West Coast 	-	<ul style="list-style-type: none"> Contractor-owned facility - government press 	-	-	Machine not of tremendous value to us, but keeps us aware of the project. There are potential shipbuilding applications.	
G	Aircraft industry	2219 aluminum alloy 7075 aluminum alloy 2024 aluminum alloy Current A-6 aircraft armor plate	T37 Unstabilized Unstabilized	<ul style="list-style-type: none"> No requirement for press over 1,000 ton 	<ul style="list-style-type: none"> 50 to 150 parts per year Lot size 25 per order 	<ul style="list-style-type: none"> (1990 year) type 7075/2024/2219 (1995 year) as above plus aluminum-lithium alloys (2000 to 2005 year) same as above 	Need extrusion capability Overhead ram (bulldozer) capability desired, as it eliminates other types of forming equipment	600	200 long x 84 wide with extensions for length and width	240 primary; 72 auxiliary	60 radius primary; 30 radius auxiliary	<ul style="list-style-type: none"> Midwest Wichita, Kansas 	-	-	-	-	Press design with accessories should be flexible to enable a sheet metal stretch stretch/draw forming with all functions CNC/DNC-controlled, with manual override. A bulldozer can be used for reverse/joggle (offset work) mainly for stretch draw-eliminates other types of forming equipment.	

FIGURE 2.4-3

APPENDIX 2.B-1

SURVEY FORM

LARGE STRETCH PRESS SURVEY FORM

The National Aeronautics and Space Administration (NASA) George C. Marshall Space Flight Center (MSFC) has contracted with Boeing Aerospace Manufacturing Technology to conduct a feasibility study for a large stretch press facility.

The objective of this study is to:

- assess and document the advantages/disadvantages of a government agency investment in a large stretch press on the order of 10000 ton capacity.
- develop a procurement specification for the press.
- provide trade study data that will permit optimum site selection.

Stretch forming offers several potential benefits such as low tooling costs, quick changeover, low distortion and minimal springback, reduced manufacturing costs with improvement in component quality, reduced raw material costs, improved tensile strength, reduced welding due to increased part size, and near net shape parts.

Current stretch form presses are in the 1000-ton range. NASA/MSFC data indicates that an investment in a large 10000-ton stretch form press would be cost effective for several applications if implementation is made in a timely manner. NASA indicates there are potential manufacturing cost savings and improvements in component quality in the stretch forming of larger tank bulkhead gore segments, ogive gore segments, and dome caps for the Space Shuttle External Tank. The capability of a large stretch press would permit the fabrication of larger gore segments and other hardware with less welding and assembly costs.

Some examples of U.S. Government agency programs with potential applications for large stretch formed parts include military space vehicles, submarines, shipbuilding, nuclear, and ordnance vehicles. Examples of commercial applications include large storage tanks, pressure vessels, antenna dishes, solar collectors, rail car and large automotive vehicles.

A large stretch press could be economically justified on the basis of other current U.S. Government and commercial industrial hardware that is being produced by other means because a large capacity stretch press is not available. Additional long-term justification can also be developed from future hardware, which could be designed for stretch forming assuming a large stretch press was available. Your assistance in identifying these potential product lines is a key element of this survey.

Individual commercial company data submittals from this survey will be handled as proprietary (confidential) information and not disseminated on other than a summary basis. Survey responses will be handled on a no-obligation/no-commitment basis in terms of individual agency or company responses.

Survey participants will be provided a summary report of the marketing survey results as requested. The Boeing Company has no business involvement in this survey other than the conduct of this study. Your assistance in participating in this survey is requested as a national interest.

PLEASE RETURN THE SURVEY ON OR BEFORE FRIDAY, JANUARY 11, 1985.

Mr. W. P. Nealson
Boeing Aerospace Company
P.O. Box 3999, M/S 6K-43
Seattle, WA 98124-2499
(206) 656-9524 or 656-9607

LARGE STRETCH PRESS SURVEY

Baseline Equipment Requirement:

- Longitudinal stretch-wrap type press with articulating jaws
- Modular design with ultimate capability of 10000 ton ram (die) force and 5000tons per jaw
- Baseline material application--stretch forming 2219-T37 aluminum plate frame maximum of 1.00" thick x 210" wide x 480" long

1. Do you presently use large (750 to 1000 ton) stretch press plate or sheet formed parts? Yes () No ()

2. Could you use a large (10000 ton) stretch press if available? Yes () No () Specify if less than 10000 ton _____

- a. When could you use such a capability? 1988/1990 ()
1990/1995 ()
1995/2001 ()

b. List potential product line applications:

IF THE ANSWERS TO QUESTIONS 1 AND 2 ARE NO, PLEASE RETURN THIS QUESTIONNAIRE FOR DATA RESPONSE INFORMATION.

3. What would be the most advantageous location for such a facility?

a. Name/Area _____ City/State _____

b. Name/Area _____ City/State _____

c. Name/Area _____ City/State _____

4. Site operational preference:

- a. Government owned, contractor operated facility ()
- b. Contractor owned facility, government owned press ()
- c. Consortium government and industry owned and funded ()

5. What other size and type of material would be of potential use over the baseline material requirement?

<u>Material Type</u>	<u>Temper</u>	<u>Material Size</u> <u>L x W x T</u>
----------------------	---------------	--

- a.
- b.
- c.
- d.

6. If specific material data is not available, please describe potential applications and year for a product line; i.e., aluminum sail boat hull sections 15' wide x 24' long (1990).

- a.
- b.
- c.
- d.

7. What are your potential production requirements:

- a. Number of parts per year _____ Batch lots
 - Lot size _____
 - Continuous production
 - Quantity/month _____
 - Other (explain)

b. Possible number of parts in five-year increments:

<u>Year</u>	<u>Material Type</u>	(Use material type code from Question 5 to indicate <u>potential mix.</u>)
1990		
1995		
2000		
2005		

8. In terms of press specifications:

- a. Would you require the capability to adapt the sheet metal jaw system to an extrusion jaw system?
 - Yes No If yes, describe:

Inches

- b. What would be your maximum bed length requirement? _____ L
- c. What would be your maximum die table length and width requirement? _____ L
 _____ W
- d. What would be your maximum jaw width requirement? _____ W
- e. What would be your maximum curved jaw chord height requirement? _____ H

9. Please add any additional comments:

Response by:

Name Telephone Number

Company Name

Company Address

City, State, Zip Code

APPENDIX 2.B-2

SURVEY MAILING LIST

Code:

* = Responded
*R = Responded/
Resulted
Requested

NASA LARGE STRETCH PRESS SURVEY CONTACTS

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LOIRE*
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(213) 770-0220

Verson All-Steel Press Company
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Mr. William Johnson, Chief
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Chief Industrial Engineer
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Mr. H. E. Woodward*
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Manufacturing Research and Development
Boeing Commercial Airplane Company
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Seattle, WA 98124
(206) 931-3173

APPENDIX C

LARGE STRETCH PRESS STUDY
NASA STUDY CONTRACT NAS8-35969

SITE SELECTION TRADE STUDY

PHASE II TASK A

APRIL 1, 1985

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SITE SELECTION

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2.3 SITE SELECTION TRADE STUDY

PHASE II TASK A

2.3.0 INTRODUCTION

Huntsville, AL is the optimum site for location of the proposed 10,000 ton stretch press. This site is for both the support of the External Tank Project and for supporting all NASA/Government Programs.

2.3.1 OBJECTIVE

The objective of this study is to conduct a parametric analysis to select the most cost effective location for a large 10,000 ton stretch press.

- A. Option I, optimum site to support the External Tank Project.
- B. Option II, optimum site for supporting all NASA/Government Programs.

2.3.2 ASSUMPTIONS

Several assumptions have been made to structure and frame the analytic effort.

- A. The operational period for the large stretch press has not been specifically defined at this time. We assume that it will commence in the 1990 timeframe.
- B. The current Space Transportation System (STS) Program schedules reflect a 234 flight manifest through 1994 at a peak rate of 24 flights per year. We have assumed that shuttle operations will continue for an undefined period beyond 1994 and may increase in peak rate above 24 flights per year.
- C. Kennedy Space Center (KSC) will continue to be the major launch facility

for the STS Program. The Vandenberg Launch Site (VLS) will remain a secondary launch facility.

- D. The external tank will remain a single source production program located at the Michoud Facility near New Orleans, LA.
- E. Should a West Coast Second Source Facility be constructed for the External Tank Program, then transportation costs identified in this study will be invalid.
- F. A Government Owned and Contractor Operated (GOCO) plant is assumed to be the proposed method of operation.

2.3.3 BACKGROUND

The maximum existing aluminum plate sizes capable of being produced today are as follows:

<u>SIZE</u>	<u>VENDOR</u>
210" x 1320"	Alcoa, Davenport, Iowa
120" x 1200"	Reynolds, Chicago, Illinois
103" x 320"	Kaiser, Ravenswood, West Virginia

The proposed large stretch press would have 210" wide articulated jaws. This would provide the capability to form the largest 210" width aluminum plate produced by Alcoa in Davenport, Iowa.

The existing Space Shuttle External Tank Program forward and aft ogive and dome gores for the LH₂ and LO₂ tanks use aluminum plate widths that range from 96" to 108". This is well within the existing capability of surface transportation by either truck or rail.

Currently ogive and dome gores are produced in the Los Angeles, CA industrial area by a combination of Space Shuttle component manufacturers as follows:

FANSTEEL PSM

Fansteel Precision Sheet Metal (PSM) is one of 12 Fansteel Inc. operating organizations. Fansteel PSM is a precision sheet metal producer for both aircraft and missile exotic sheet metal parts. Over 58 different Space Shuttle components are built by PSM. The external tank dome cap, 144" diameter, appears to be the largest single diameter part currently fabricated by PSM.

Fansteel PSM spin forms the dome cap from a round plate and after machining ships the part to Aero Chem in Orange, CA, about 30 miles one way for chem milling. It is then returned to Fansteel for additional manufacturing operations prior to shipment by truck to Martin-Marietta located at the Michoud Facility near New Orleans, LA. Fansteel PSM expressed a desire to be considered as a location for a large stretch press.

AERO CHEM

Aero Chem is located at Orange, CA and does all of the chemical milling for the external tank components in the Los Angeles region. Aero Chem has suggested that a large stretch press be located near their facility. Their major concern is with the inter-city transportation constraints posed by the larger external tank parts.

AIRCRAFT HYDROFORM

Aircraft Hydroform (A/C HF) is a major facility for products requiring hydro formed parts. They have presses located at both Gardenia and

Victoria, CA. A/C HF is the largest user of stretch and forming presses in the Los Angeles area. They have stretch press capability up to 1,600 tons. Consideration of A/C HF for a proposed location of a large stretch press requires relocation to a new plant site.

2.3.4 APPROACH

The objective of the Phase I Task B large stretch press survey was to identify the potential user market. The physical dimensions of the proposed stretch press to handle 1" thick x 210" wide x 480" long aluminum plate was defined on the User Survey Form.

The User Survey Forms were distributed to over 60 various government agencies, aluminum suppliers, the Aerospace Industry and other various commercial and industrial companies. The governmental agencies included: U. S. Air Force, U. S. Army, U. S. Navy, Department of Defense, Department of Transportation and Department of Commerce. Other potential customers included: aluminum suppliers, the Aerospace Industry, stretch press equipment, design and fabricators as well as other commercial industries.

Response to the survey by NASA, Department of Defense and industry users, up to and beyond the year 2000, was for plate sizes within the proposed stretch press capabilities as defined in the User Survey. The majority of potential users have not identified future width requirements beyond 200". However, whenever larger dimension capability becomes available to industry, it is only a matter of time before components are designed which will utilize the larger capability.

The approach used in the Site Selection Survey was to look at the placement of a large stretch press in a location that would use its full capability to handle 1" thick x 210" wide x 480" long aluminum plate.

2.3.5 ANALYSIS

The capability to form components from 1" thick x 210" wide x 480" long aluminum plate requires the analysis of the overall transportation system from producer to manufacturer to ultimate user.

Existing surface transportation by either truck or rail is not feasible for parts using 1" thick x 210" wide x 480" long aluminum plate which equates to part sizes 17.5' wide x 40' long. See **FIGURE 2.3.5-1** for surface transportation size restrictions. The use of wide load permits and pilot cars makes truck transportation over long distances economically impractical.

A logical method for transportation of 17.5' wide x 40' long aluminum plate over long distances becomes feasible only by use of either water routes or air transport by Super Guppy. All three large plate producers have water access. See **FIGURE 2.3.5-2** for the inland waterway system which inter-ties all three large plate producers.

TRUCK AND RAIL TRANSPORTATION

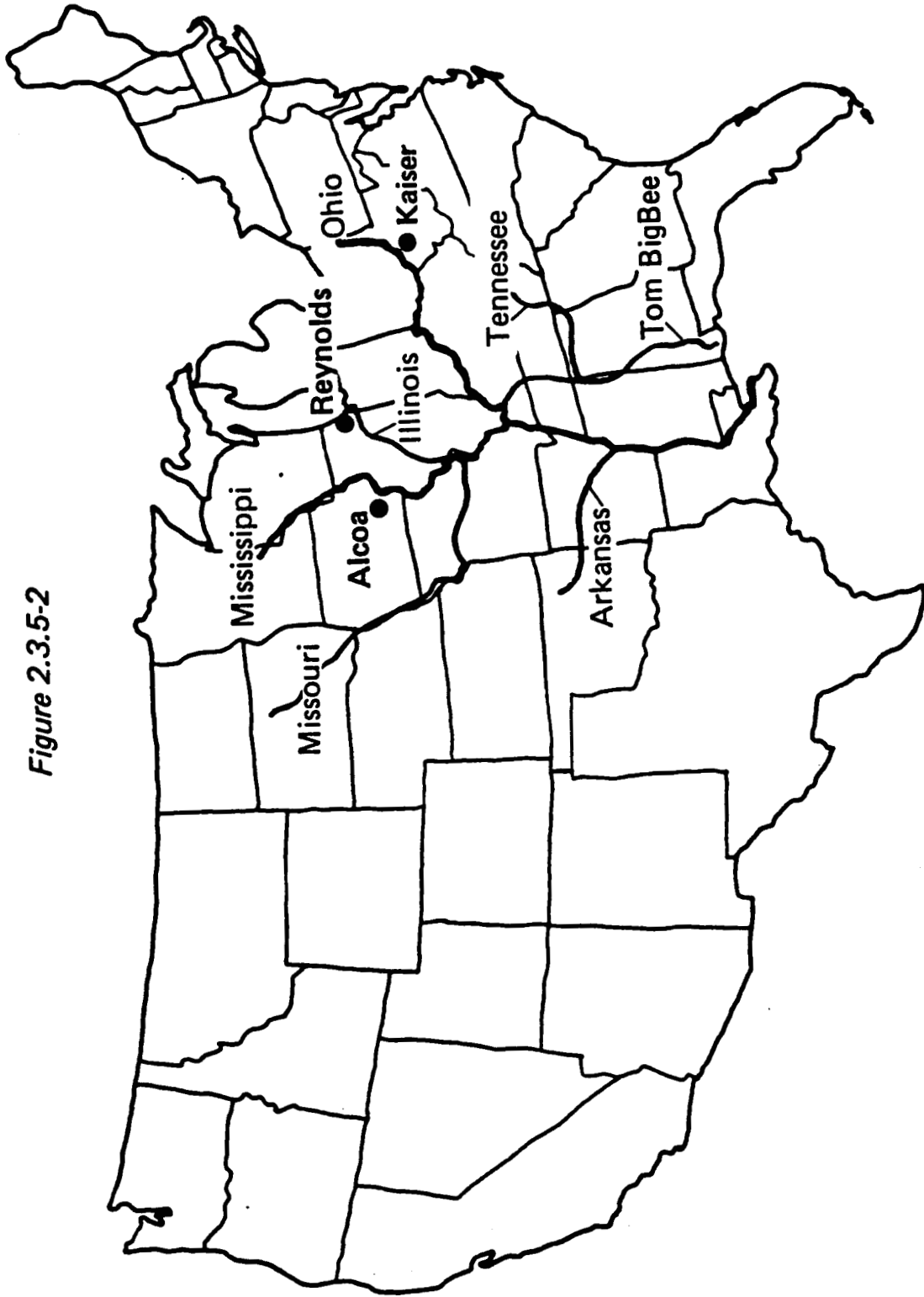
FIGURE 2.3.5-1

	<u>WIDTH</u>	<u>LENGTH</u>	<u>HEIGHT</u>	<u>GROSS WEIGHT</u>	<u>NET PAYLOAD</u> ⁽³⁾
Truck ⁽¹⁾	8'-6"	65'	13'-6"	80,000 lbs.	46,000 lbs.
Rail ⁽²⁾	10'-6"	100'	15'-0"	154,000 lbs.	100,000 lbs.

1. Dimensions listed are overall truck and trailer dimensions rather than net payload dimensions. The normal truck bed height is 50" above the road surface and Lo-Boy trailer height is 22". Net usable height for payload becomes 9'-4" and 11'-8" respectively using 13'-6" as a maximum overall height.
2. Dimensions listed are overall general purpose railcar dimensions rather than net payload dimensions. Extra heavy duty and depressed center flatcars for extraordinary shipments exist in limited numbers.
3. Net Payload is weight available for components transported. A 1" thick x 210" wide x 480" long aluminum plate weighs approximately 10,000 lbs. each.

Tennessee River and Inland Waterway System

Figure 2.3.5-2



<u>PRODUCER</u>	<u>LOCATION</u>	<u>WATERWAY/RIVER</u>
Alcoa	Davenport, Iowa	Mississippi
Kaiser	Ravenswood, WV	Ohio
Reynolds	Chicago, IL	Illinois

Use of air transportation by Super Guppy for transporting finished large components may be economical from the manufacturer to the user. However, shipment by air from the producer of raw material plate to the manufacturer is questionable.

A 1" thick x 210" wide x 480" long aluminum plate weights approximately 10,000 lbs. each. Air Bus Industry of France, which owns the current fleet of Guppy and Super Guppy aircraft, has minimum net payload capacity for handling large volumes of aluminum plate. The TAC Heavy Lift Air Cargo aircraft, the largest lift capability existing, has a maximum net payload capacity of 55,000 lbs. This equates to a total of 5 aluminum plates 1" thick x 210" wide x 480" long and must include the weight of any cargo tie down system in excess of 5,000 lbs.

The low value cost per weight of each 10,000 lb. 1" x 210" x 480" aluminum plate makes consideration of air transportation economically unfeasible for any long term production programs.

However, after application of intensive labor and machining or milling operations to blank aluminum plates, plus the reduction in weight by these processes, air transportation may be feasible.

For example, Aero Chem located in Orange, CA currently does all of the chemical milling for Los Angeles, CA area external tank component manufacturers. During a plant tour of their facilities it was stated that over 63% of the total aluminum plate weight was removed during the chemical milling process. Therefore finished aluminum plate weights average only 40% or less of the original raw material plate furnished to the fabricator from the producer.

SITE LOCATION REQUIREMENTS

The site selection process for the location of a large stretch press must take into consideration ancillary equipment and additional facilities besides the stretch press.

Ancillary equipment and additional facilities required to support a stretch press operation includes:

- A. Heat treat or aging facilities
- B. Chemical milling
- C. Mechanical milling
- D. 5 axis machining
- E. Tool fabrication facilities
- F. Storage and handling capability

The ideal concept would be for all functions to be at one contiguous location to reduce both handling and transportation. In addition, the distance between the raw material producer and the manufacturer and then the ultimate user should be minimized wherever possible.

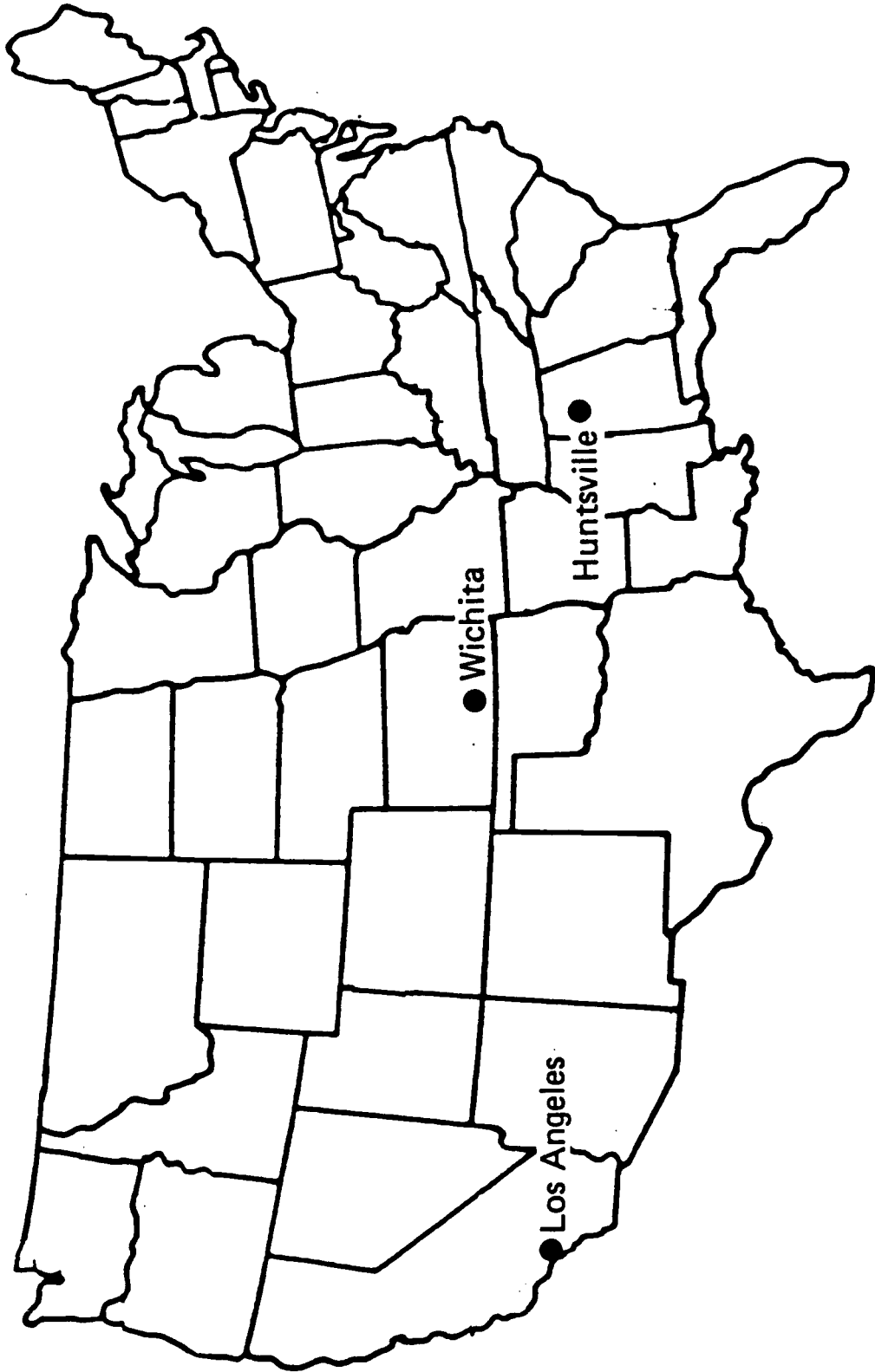
SITE CANDIDATES

Several existing and potential sites were considered for evaluation. See **FIGURE 2.3.5-3** for site locations. These include:

<u>REGION</u>	<u>LOCATION</u>
Southwest	Los Angeles, CA
Midwest	Wichita, KA
Southeast	Huntsville, AL

Site Location Candidates

Figure 2.3.5-3



SOUTHWEST

The large number of manufacturing facilities within the southwest region makes the Los Angeles Basin a prime candidate for the location of a stretch press facility.

Currently the Space Shuttle Program utilizes the capability of this region to manufacture various elements of the Space Shuttle Orbiter, main engine and external tank components.

Site selection candidates include the following:

<u>FIRM</u>	<u>LOCATION</u>
1. Fansteel PSM	Los Angeles, CA
2. Aero Chem	Orange, CA
3. Aircraft Hydroform	Gardenia, CA

All three southwest region potential sites are within a 30 mile radius of the greater Los Angeles area. Today Fansteel PSM, Aero Chem and Aircraft Hydroform fabricate components for the Space Shuttle Program. Any consideration for locating a large stretch press in this area would benefit from the existing experience and capability of the current labor force.

However, when looking at the capability of the Los Angeles area to form parts up to the maximum capability of the proposed large stretch press, 1" thick x 210" wide x 480" long, other factors become extremely important.

Transportation by either truck or rail of large existing 1" thick x 210" wide x 480" long or 17.5' wide x 40' long aluminum plate from the raw material

producer to the Los Angeles area is impractical. Shipment by water transportation from the producer, see **FIGURE 2.3.5-2**, via the inland waterway, the Gulf of Mexico, Panama Canal and Pacific Ocean is possible.

Although the water route is possible for the shipment of 1" thick x 210" wide x 480" long aluminum plate, transportation time and cost makes the Los Angeles, CA area economically non-competitive when other potential site locations are considered.

The installation of a large stretch press within the Los Angeles, CA area would require a new site for all three proposed Southwest Area locations. In addition, ancillary equipment and support facilities would require either extensive renovation or new construction.

The Nationwide Construction Cost Index, based on the Means Construction Cost Data, see **FIGURE 2.3.5-4**, ranks California as the most costly of all potential site locations for new construction.

The Alexander Grant & Co. study evaluates each state's manufacturing "Business Climate". The "Business Climate" refers to a collection of factors viewed by manufacturers as important to their business. See **FIGURE 2.3.5-5** for a listing of these factors. The factors are oriented to the cost of doing business. The Alexander Grant & Co. study ranks all 48 contiguous states against each other based on the values of each of the 23 measurement factors. This is the fourth annual study. The methodology of the study is the same identical approach as used in previous years.

The Business Climate Study, see **FIGURE 2.3.5-6**, ranks California 26th out of 48 with one being best and 48th worst.

NATIONWIDE CONSTRUCTION COST INDEX

FIGURE 2.3.5-4

<u>STATE</u>	<u>INDEX</u>	<u>DOLLARS IN MILLIONS *</u>
CALIFORNIA	1.05	\$57.7
WASHINGTON	1.00	55.0
OREGON	.96	52.8
LOUISIANA	.88	48.4
MARYLAND	.86	47.3
TEXAS	.85	46.7
FLORIDA	.83	45.6
ALABAMA	.82	45.1
GEORGIA	.82	45.1
MISSISSIPPI	.82	45.1
VIRGINIA	.82	45.1
NORTH CAROLINA	.79	43.4
SOUTH CAROLINA	.77	42.4

* Assumes a total construction cost base of \$55 million for comparison purposes. This includes an estimated rough order of magnitude of \$25 million for the stretch press and \$30 million for the structure to house the stretch press.

BUSINESS CLIMATES STUDY CRITERIA

FIGURE 2.3.5-5

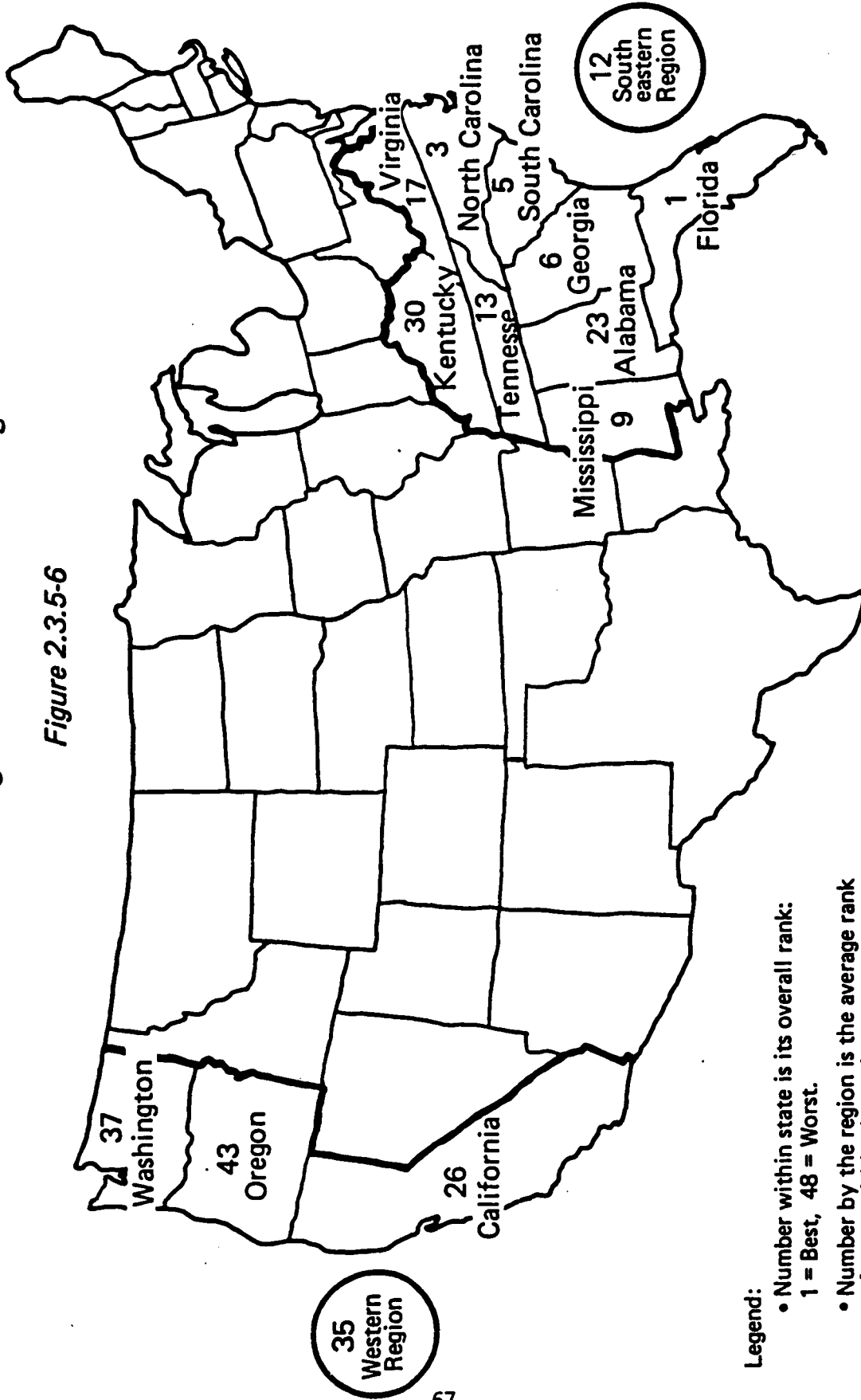
	<u>SOUTHEAST</u>	<u>WEST</u>
1 Energy Costs (Fuel & Electric M BTU)	\$ 3.62	\$ 3.17
2 Wages (Average Hourly)	\$ 6.60	\$ 9.49
3 Unionization	15.6%	29.2%
4 Workers Compensation Insurance (per \$100 of Payroll)	\$ 2.95	\$ 6.96
5 Unemployment Compensation (per Covered Worker)	\$ 83	\$ 117
6 Location to Market Place (75% of Market)	700 miles	2,000 miles
7 Value Added (per Dollar of Production Payroll)	\$ 3.67	\$ 3.68
8 Change in Wages (3 years)	31%	34%
9 Taxes (per \$1000 Personal Income)	\$ 105	\$ 111
10 Unemployment Compensation (per Covered Worker)	\$ 213	\$ 267
11 Manhours Lost (2 years)	.092%	.170%
12 Maximum Workers Compensation Payment (per week)	\$ 191	\$ 228
13 Expenditure Growth vs Revenue Growth (3 years)	1.13%	1.27%
14 Vocational Education Enrollment (Percent of Population)	2.12%	3.01%
15 High School Educated Adults (Percent over 25 yrs old)	57.2%	75.1%
16 Environmental Control (Percent of State Expenditure)	0.23%	0.47%
17 Changes in Taxes (3 years, \$1,000 Personal Income)	-7.62%	-18.71%
18 Changes in Unionization (2 years)	-6.29%	-7.84%
19 Debt (per Capita)	\$1,264	\$2,495
20 Population Density (per Square Mile)	105	80.6
21 Population Change (3 years in 1,000's)	409	835
22 Hours Worked (per week)	39.8	38.7
23 Welfare Expenditure (per Capita)	\$ 152	\$ 255

Data from Alexander Grant & Company using 1982 Data Base - 4th Study

Business Climate Study*

Western Region vs. Southeastern Region

Figure 2.3.5-6



- Legend:
- Number within state is its overall rank:
1 = Best, 48 = Worst.
 - Number by the region is the average rank of states within the region.

*Data from Alexander Grant and Company, using 1982 data base, fourth study.

MIDWEST

The site candidate is Boeing at Wichita, Kansas. The Boeing Wichita Company currently operates 150 ton, 250 ton, 300 ton and 1,500 ton stretch form presses. Within the Boeing Company there are 21 sheet metal and stretch form facilities of 150 tons or more capacity. The 1,500 ton press at Wichita, KA is used in addition to its plate forming capabilities as a back-up for stretching extruded aluminum aircraft wing chords. This supplements the Boeing Seattle area capability. The 1,500 ton transverse and longitudinal press is the largest of its type in the U.S. Collectively at all locations Boeing has the largest number of stretch presses in the world.

Capability to deliver large 1" thick x 210" wide x 480" long aluminum plate by water transportation from the raw material producer to Wichita, KA does not exist. Therefore Wichita is not considered a candidate for location of the large stretch press.

The site selection process must, however, consider second source capability as a back-up to existing external tank parts fabrication. The existing external tank ogive and gore sections for the LH₂ and LO₂ tanks use aluminum plate widths between 96" and 108". This is well within the capability of existing truck and rail surface transportation, see **FIGURE 2.3.5-1**. Therefore, consideration of Boeing Wichita as a back-up second source facility to existing external tank parts fabricators has merit.

SOUTHEAST

Huntsville, AL is located on the banks of the Tennessee River. A stretch press location in the vicinity of Huntsville, AL provides a direct water

route from the three major raw material producers to Huntsville. See **FIGURE 2.3.5-2**. Water shipment from Huntsville, AL to the Michoud Facility near New Orleans, LA can also be accomplished via the Tombigbee Waterway to Mobile, AL and through the Gulf of Mexico to the external tank assembly plant at Michoud, LA.

The Redstone Arsenal located at Huntsville, AL has existing barge facilities that were constructed in support of the Saturn Program. Should the Redstone Arsenal be considered as the site location for the proposed stretch press, a cost savings by use of existing barge capability would be realized.

The Shop and Assembly Building 4707 or the Machine Shop/Neutral Buoyancy Simulator Building 4705 are two potential locations for the stretch press facility if located at Redstone Arsenal. Each structure has high bay area served by existing cranes.

<u>BUILDING</u>	<u>CRANE</u>	<u>HOOK HEIGHT</u>
4705	10 ton	36'
4707	20 ton	24'

Consideration should be given to the operation of the proposed stretch press as a Government Owned, Contractor Operated (GOCO) Facility. This allows private industry the capability to become users of the press capacity.

Other locations in the vicinity of Huntsville, AL are feasible as long as access to the Tennessee River is maintained.

2.3.6 CONCLUSIONS

The proposed location for a large capacity stretch press, capable of forming 1" thick x 210" wide x 480" long aluminum plate, requires water access from the three raw material producers. Without direct water access, transportation costs become prohibitive when other modes of transportation such as air freight are used.

FIGURE 2.3.5-2 shows the location of Alcoa at Davenport, Iowa on the Mississippi River, Kaiser at Ravenswood, West Virginia on the Ohio River and Reynolds near Chicago, IL on the Illinois River. To maintain flexibility of receiving aluminum plate from all three producers, a stretch press site location should be downstream from the point where all three rivers intersect. This point is where the Ohio River meets the Mississippi River between Missouri, Illinois and Kentucky. Any site location downstream from this junction can be served economically by all three raw material producers.

The existing external tank fabricators located in the Los Angeles area currently use truck transportation. They receive plate from the raw material producers and deliver the formed parts to the Michoud Facility near New Orleans, LA. However, the existing 8' and 9' plate widths can be produced at many locations in close proximity to the Los Angeles Basin. When today's maximum plate sizes are considered, 1" thick x 210" wide x 480" long, the closest producer is over 2,000 land miles and 3,000 water miles away from Los Angeles. See **FIGURE 2.3.5-2** for aluminum plate producer locations.

As plate sizes increase and exceed the capability of either truck or rail surface transportation, then water and air becomes the only modes of transportation capable of handling the larger sizes.

The Los Angeles area then becomes an economically unfeasible location for the stretch press. Placement of a stretch press in a location to handle 1" thick x 210" wide x 480" long plate excludes Los Angeles from consideration.

The use of Wichita, KA as a second source back-up capability to the existing Los Angeles area fabricators is feasible due to the small sized plate widths that range between 8' and 9'. Both truck and rail transportation can be used. Consideration of Wichita for location of the large NASA stretch press is impractical due to the lack of direct water access.

A large stretch press location at Huntsville, AL provides capability to receive and ship, by direct water access, the largest aluminum plate sizes produced.

Advantages also exist in the use of truck shipments for smaller sized plate. Huntsville is within 500 miles or 1 day truck travel time of all major producers. See **FIGURE 2.3.6-1**. The truck travel time is one day from Huntsville, AL to New Orleans versus 4 days truck travel time from Los Angeles to either New Orleans or Huntsville.

Truck freight cost penalties are also incurred when shipping from Los Angeles to either New Orleans or Huntsville. Los Angeles averages 2.8 times greater cost to New Orleans in comparison from Huntsville to New Orleans. See **FIGURE 2.3.6-2**.

Electrical power, in the southeast, for the operation of the proposed stretch press along with power requirements for the ancillary equipment and support facilities is substantial.

TVA is the largest energy sales producer in the United States with a generating capacity in excess of 31,000 MW. TVA provides power to 160 municipal and cooperative distributors as well as Federal, Nuclear, Aerospace and military installations. The service area covers 80,000 square miles and parts of seven states in the southeast region.

Comparison of typical residential electrical bills places TVA near the bottom of the list.

<u>MAJOR U. S. CITIES</u>	<u>JULY - MONTHLY COMPARISON</u>
New York, NY	\$ 157
Chicago, IL	106
Boston, MA	88
St. Louis, MO	64
Los Angeles, CA	58
TVA Service Area	47

By the late 1980's, TVA rates should be significantly lower than the nation and southeastern regional averages. The large capacity and diversification of generation types provides an advantage over other electric utility areas.

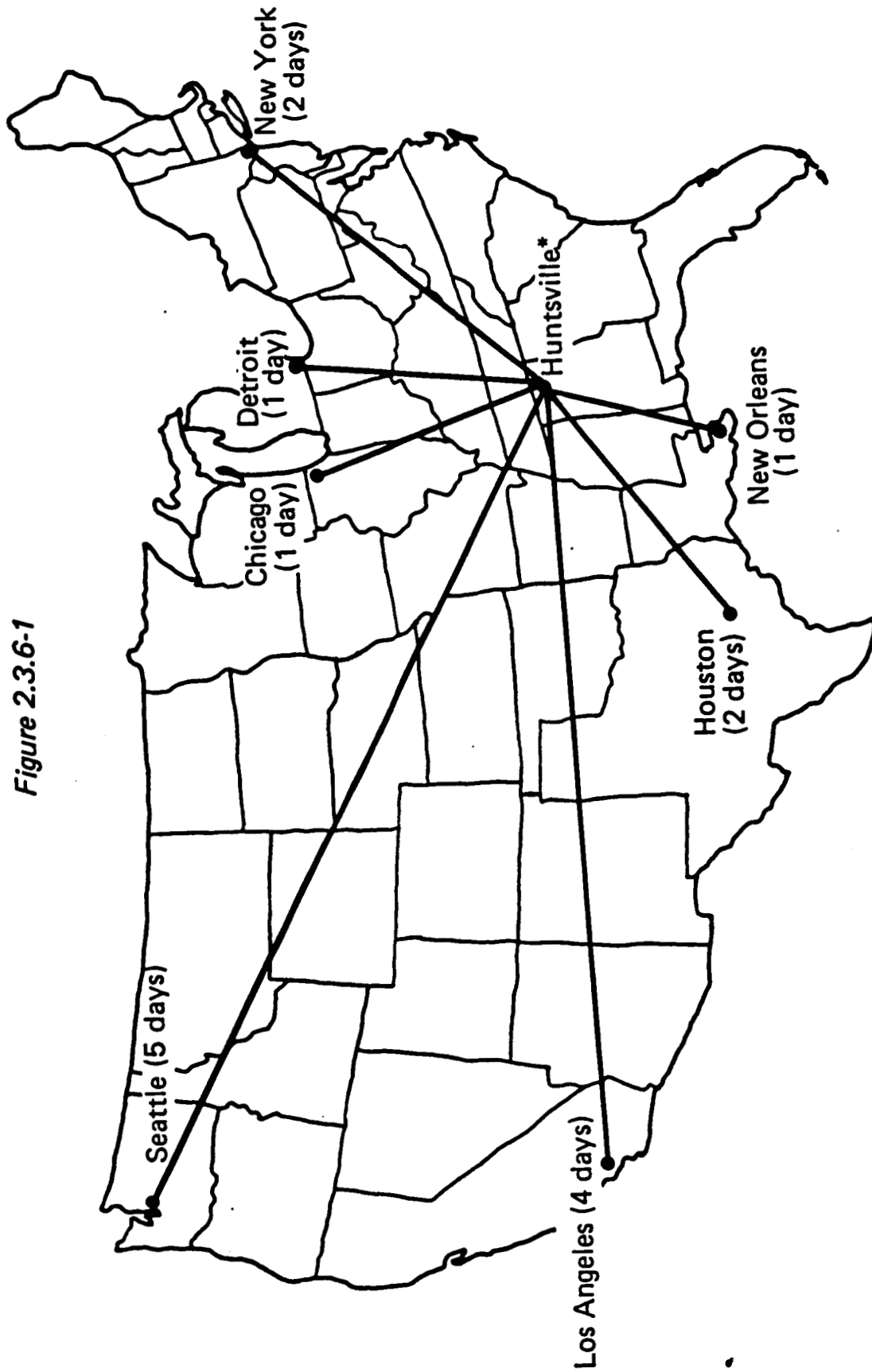
The southeast region has many advantages in comparison to both the midwest and southwest regions.

- A. Manufacturing wages are lower at \$6.60 in the southeast versus \$9.49 in the southwest. See **FIGURE 2.3.5-5**.
- B. Office skill wages are a 21% savings.
- C. Management wages are a 10% savings.
- D. The southeast states are right to work states.

- E. Within one day's delivery time of 76% of this country's major suppliers and population centers.
- F. Provides reduced freight costs.
- G. Excellent business climate.
- H. Excellent labor market.
- I. Ample supply of utilities at moderate cost.
- J. Attractive liveability.
- K. High technology area.
- L. Advantageous cost of living.

Truck Travel Time

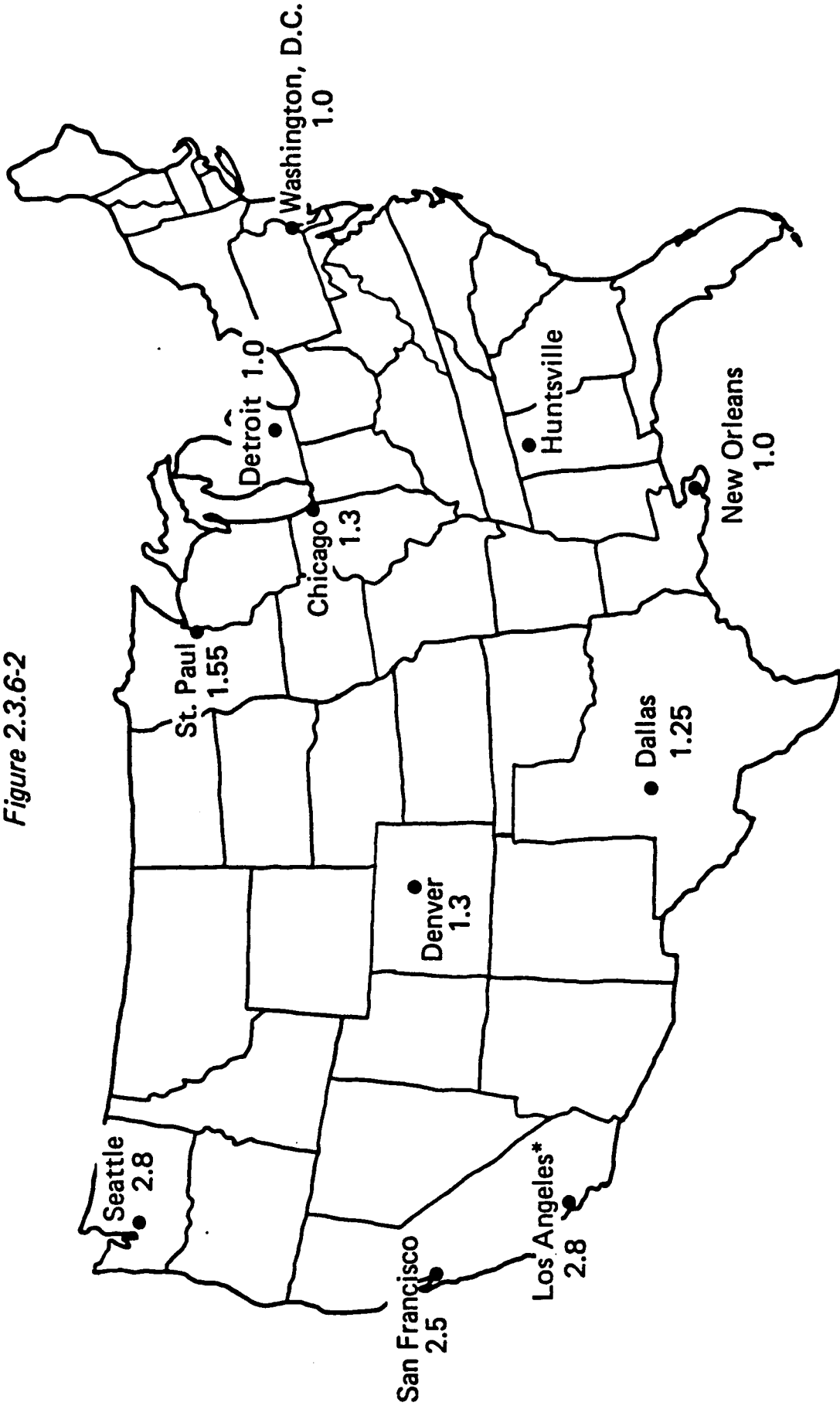
Figure 2.3.6-1



*Huntsville is located within 500 miles of 76% of the major U.S. markets.

Truck Freight Cost Index

Figure 2.3.6-2



*Truck shipments from Los Angeles to Huntsville are 2.8 times greater than from New Orleans to Huntsville.

2.3.7 RECOMMENDATIONS

Huntsville, AL is the recommended site for the 10,000 ton stretch press for both Option I - the Optimum Site recommended for the External Tank Project and Option II - the Optimum Site recommended for supporting all NASA/Government Programs.

The location at either the Redstone Arsenal or some other site on the Tennessee River provides the capability to receive and ship large components by direct water access via the inland waterway system.

The location of Huntsville, AL in direct alignment between the raw material producers and the user in Michoud at New Orleans, LA eliminates 4,000 miles of truck travel or 6,000 miles of water travel that otherwise would be incurred with a Los Angeles area location.

Sufficient undeveloped land is available within the existing Redstone Arsenal boundaries to eliminate the need for land acquisition if other Huntsville area sites are found to be impractical for economic reasons.

The cost penalties incurred by truck to ship from the west coast to Huntsville or New Orleans is also true for the railroad rate structure. See **FIGURE 2.3.7-1**.

Ancillary equipment capability and additional facilities required to support a large stretch press operation include the following:

- A. Heat treat or aging facilities
- B. Chemical milling
- C. Mechanical milling

- D. 5 axis machining
- E. Tool fabrication facilities
- F. Storage and handling capability

The largest existing support capability for the three different geographical regions are as follows:

<u>REGION</u>	<u>LOCATION</u>	<u>FIGURE</u>
Southwest	Los Angeles, CA	2.3.7-2
Midwest	Wichita, KA	2.3.7-3
Southeast	Huntsville, AL	2.3.7-4

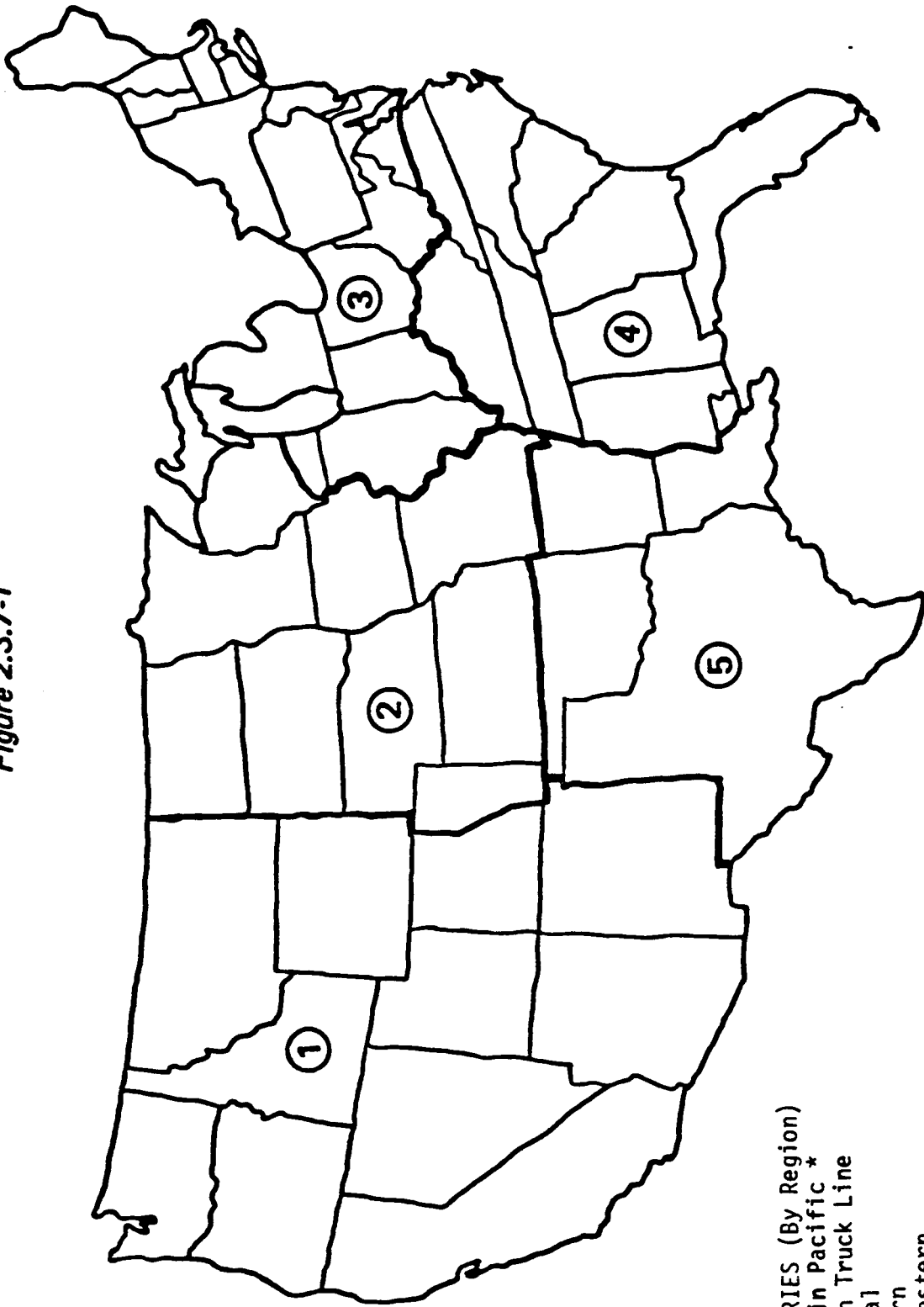
As part sizes increase in dimensions to fully utilize the 1" thick x 210" wide x 480" long capacity of the proposed NASA stretch press and as part sizes exceed existing capability of support facilities, then construction of new ancillary equipment and facilities should be undertaken. Consideration could then be given, at that future time, with the use of inland water transportation, to locate the new larger sized support facilities in closer proximity to the stretch press site.

There is also a potential for developing major external tank sub-assembly capability along the inland waterway system to the Michoud Facility near New Orleans, LA.

Industrial diversification would be enhanced. It would also reduce the potential for a local natural disaster by dispersing facilities. Space at the Michoud Facility could be used for other additional product applications.

Railroad Rate Structure

Figure 2.3.7-1



RAIL TERRITORIES (By Region)

1. Mountain Pacific *
2. Western Truck Line
3. Official
4. Southern
5. Southwestern

* Only the Mountain Pacific territory rates are higher than the other territories due to limited mountain range routes

SOUTHWEST REGION SUPPORT CAPABILITY

FIGURE 2.3.7-2

	<u>CHEMICAL</u> <u>MILLING</u> (1)	<u>HEAT</u> <u>TREAT</u> (2)	<u>5 AXIS</u> <u>MACHINING</u> (3)
LENGTH	40'	30'	180'
WIDTH	12'	4'	13'
HEIGHT	16'	5'	2'

1. Chemical Milling, Chem Energy Company, San Diego, CA.
2. Heat Treat, Cal-Doran, Los Angeles, CA or Aerospace Aluminum Heat Treating Company, Paramount, CA.
3. 5 Axis Machining, Rohr Industries, Chula Vista, CA.

MIDWEST REGION SUPPORT CAPABILITY *

FIGURE 2.3.7-3

	CHEMICAL <u>MILLING</u>	HEAT <u>TREAT</u>	5 AXIS <u>MACHINING</u>
LENGTH	24'	24'	45'
WIDTH	4'	8'	12'
HEIGHT	7'	8'	2'

* Boeing Military Airplane Company, Wichita, KA.

SOUTHEAST REGION SUPPORT CAPABILITY

FIGURE 2.3.7-4

	CHEMICAL <u>MILLING</u>⁽¹⁾	HEAT <u>TREAT</u>⁽²⁾	5 AXIS <u>MACHINING</u>⁽³⁾
LENGTH	50'	48'	50'
WIDTH	10'	19'	6'
HEIGHT	15'	15'	2'

1. Chemical Milling, Lockheed Georgia, Atlanta, GA.
AVCO, Nashville, Tennessee
(C-5 Chem Milling relocated to Texas and California.)
2. Heat Treat, Pinson Valley Heat Treating Co., Birmingham, AL.
3. 5 Axis Machining, Lockheed Georgia, Atlanta, GA.
AVCO, Nashville, Tennessee

APPENDIX D

**LARGE STRETCH PRESS STUDY
NASA STUDY CONTRACT NAS8-35969**

PRESS DESIGN/PROCUREMENT SPECIFICATION

PHASE II TASK B

APRIL 1, 1985

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2.4 LARGE STRETCH PRESS DESIGN/PROCUREMENT SPECIFICATION

PHASE II TASK B

2.4.0 OVERVIEW

Two separate specifications were developed by Boeing in conjunction with the two major competitive U.S. equipment manufacturers. These manufacturers assisted in this study with no cost to this contract.

Boeing specification number 4427 was developed for a 5,000-ton (2,500 tons/jaw) stretch press and Boeing specification number 4437 for a 10,000-ton (5,000 ton/jaw) stretch press.

Two separate specifications were developed by Boeing to provision for two separate but distinct requirements from the NASA contract NAS 8-35969 Statement of Work.

- A. Requirement for the use of a stretch press for the fabrication of existing size or larger size (up to 150% wider) external tank (ET) premachined components.
- B. Requirement for forming larger 2219 aluminum alloy size plate (1" thick x 210" wide x 480" long). This size material is not only significantly larger than existing ET plate requirements but it is also larger than existing U.S. aluminum manufacturer currently produce.

Our Phase II Task B study provisions for both size presses. The next separate phase of this study by NASA/MSFC with stretch press manufacturers should be

for a preliminary design contract based on NASA/MSFC's analysis of their press size and optimal feature requirements. The next phase should be a final design competition by the manufacturers based on these requirements.

2.4.1 BACKGROUND

The Boeing Phase I Task A study indicates that to stretch from existing configuration ET components a press in the 3,000-ton (1500 tons/jaw) range is more than adequate for the fabrication of larger (wider) ET tank candidate parts. Our industrial survey was made initially on the requirement for a 5,000-ton (2500 tons/jaw) press based on our analysis of the potential growth of stretch formed parts for larger space vehicle requirements, i.e. 67' diameter vs. 30' existing ET diameter.

The largest current design production stretch presses are in the 1,500-ton range (750 tons/jaw) and these presses are utilized by both us and friendly foreign aircraft manufacturers for forming aircraft major body skins in large crown sections to reduce detail fabrication parts costs and reduce in process flow times.

The state of the art in stretch press design has changed dramatically in the last decade and current designs dramatically improve the flexibility and potential of the stretch press. The additive features of smaller insert jaws, insert extrusion adaption dies, overhead die table (bulldozer) have improved both application and utilization. In addition, new air bearing die handling capability enhances changeover with reduced requirements for very heavy overhead cranes.

2.4.2 PRESS SIZE/COST CONSIDERATIONS

Based on our development of the press specifications with both of the prime U.S. stretch press manufacturers. The following size considerations are applicable:

A. 10,000-ton press (5,000 tons/jaw)

1. Size Manufacturer C (ROM estimate only)

65' wide x 120' long x 30' deep x 24' high (above ground)

2. Size manufacturer L (ROM estimate only)

45' wide x 100' long x 30' deep x 24' high

3. Approximate weight 5 to 7 million pounds. Boeing estimate \$5/lb = \$25 to \$30 million press cost. Weight of largest single fabricated part 400,000 lbs.

4. Foundation cost approximately \$1.2-\$1.5 million

5. Lead time 3 years

6. Hydraulic system 5000 psi

7. The requirement for rotation of the press jaws (articulating jaws) is not advisable for a 10,000-ton press. There are divergent opinions from the two press manufacturers on the requirement for articulating jaws—one manufacturer does not recommend them but the other says it is feasible but at a much higher cost in addition to adding approximately 20' to the length and width of the press. These differences are due to the two different manufacturers design concepts.

8. No estimate of the cost or size for an overhead crane for die handling or material handling was provisioned.

B. Large stretch press technical comparisons

The following data as provided by one manufacturer is presented for comparative press size purposes:

1. 10,000 ton press

Tension cylinders (2)

Bore 40" dia

Rod 18" dia Net area each 1002 sq in

Die table

Bore 52" dia

Rod 24" dia Net area each 1671 sq in

2. 5000 ton press

Tension cylinders (2)

Bore 29" dia

Rod 13" dia Net area each 523 sq in

Die table

Bore 36" dia

Rod 18" dia Net area, each 764 sq in

3. Either press size would require waterway access for press assembly and installation due to its large component size and weight for comparative purposes with larger presses described in paragraph 2.4.2.A a 1500 ton (750 tons/jaw) press installed in Wichita, Kansas was as follows:

Press Type—1500 ton transverse/longitudinal sheet stretch forming machine with power curvable jaws.

Press size—27' wide, 85' long, 28' deep, 8' high (above ground)

Weight (approximately) 1 million pounds

Foundation size (approximately) 30' wide x 90' long x 29' deep

Hydraulic system—2750 psi/168 GPM

Jaw opening 1"

Function/stretch forms A/C skins under 1/2 inch thick up to 70" wide x 30' long

Cost \$4.5 million (approximately)

Overhead crane—25-ton capacity with spreader bars

4. As a general rule the larger the press tonnage the higher the lower end tonnage control, i.e., a 10 year old 1000 ton press cannot normally control lower limits under 100 to 150 tons (10%). Newer press control systems now in operation can perform to a 5% lower limit and the latest design control systems per the equipment manufacturers can perform as low as 2%.

2.4.3 BOEING SPECIFICATION NUMBER 4427 5000-TON STRETCH PRESS

**SPECIFICATION
FOR
5,000 TON TRANSVERSE LONGITUDINAL CURVED JAW SHEET STRETCH
FORMING MACHINE, COMPUTER NUMERICALLY CONTROLLED**

Specification No. 4427
January 14, 1984

1.0 SCOPE

1.1 Purpose

This specification provides a standard for the procurement, design, installation, performance and inspection for the subject equipment. It lists minimum requirements and is not to limit design advances, safety features, ease and convenience of operation and maintenance.

1.2 Intended Use

The equipment described by this specification is to be utilized for stretch forming of ferrous and non-ferrous alloy sheets into complex contoured shapes.

2.0 CODES AND STANDARDS

Latest revisions shall apply.

- 2.1 The Joint Industrial Council (JIC) Electrical Standards, drawings only.
- 2.2 The United States of America Standards Institute (USASI).
- 2.3 The National Electrical Code (NEC).
- 2.4 National Aerospace Standard 930, Stretch Forming Machines-Airframes.
- 2.5 Occupational Safety and Health Administration (OSHA).
- 2.6 State and Local Electrical and Labor Codes.
- 2.7 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII.
- 2.8 Electronic Industries Association Standard RS-281, Numerical Control Construction Standards - Numerical Machine Tool.
- 2.9 Joint Industrial Council (JIC) Hydraulic Standards for Industrial Equipment, H-1-1973.
- 2.10 Joint Industrial Council (JIC) Pneumatic Standard for Industrial Equipment 1957.

3.0 TECHNICAL DATA

The seller shall be completely responsible for the successful design, fabrication, complete installation and testing of the machine. Seller shall provide qualified field engineering personnel to supervise the erection and installation of the machine and conduct checkout, testing and training.

3.1 Mechanical

Special design consideration shall be given to machine disassembly to permit equipment shipment by most economical method.

3.1.1 Description

3.1.1.1 NAS 930 Type I transverse and Type II longitudinal combination stretch forming machine with power curvable sheet jaws mounted in carriages transversely positionable during machine set-up and stretching operation. The die table shall be tiltable in vertical plane parallel to the sheet jaws.

3.1.1.2 The machine shall have a maximum tension tonnage of 2500 tons per jaw for a total machine rating of 5000 tons.

3.1.1.3 Part sizes ranging from .200 inch to 1.00 inch in thickness, 60 inches to 210 inches in width, and to 480 inches long.

3.1.2 Die Table Capacity

3.1.2.1 Size: Length 210 inches minimum
Width 36 inches

3.1.2.2 Tonnage: Maximum 5,000 tons
Minimum Operate under position control

3.1.2.3 Tilt angle $\pm 15^\circ$ from horizontal

3.1.2.4 Stroke Approx. 100 inches

3.1.2.4.1 Distance between centerline of jaw trunion and die table top surface. (Jaw horizontal and stroke down.) Approx. 80 inches

3.1.2.5 Table rotation 90°

3.1.2.6 Speeds: Positioning 0 to 20 IPM
Forming .2 to 8 IPM

3.1.3 Jaw Capacity

3.1.3.1 Jaws, curved (Primary):

3.1.3.1.1 Distance between Jaws:

Maximum	480 inches
Minimum (Horizontal)	16 inches
Minimum (Vertical) (ϕ to ϕ of jaws)	100 inches, with tension cylinders fully retracted

3.1.3.1.2 Stroke, each Jaw:

Minimum, carriage cylinders	90 inches
Minimum, tension cylinders	24 inches



3.1.3.1.3	Length of Jaws, straight:	
	Maximum (effective)	210 inches
	Minimum at Maximum Tonnage	160 inches
3.1.3.1.3.1	Curvature, minimum radius	80 inches down
	Both directions ("S" curve)	320 inches up
3.1.3.1.4	Tonnage (per jaw)	
	Maximum	2500 tons (over min. 160 inches)
	Minimum	100 tons or less (tension cylinder)
	Maximum	100 tons (per segment outboard of center 160")
	Maximum	282 tons (per segment in center 160")
3.1.3.1.5	Carriage Tonnage (per jaw) (Maximum)	2500 tons
3.1.3.1.6	Swing: Setup	Infinitely adjustable from horizontal through vertical with tangency controls.
3.1.3.1.6.1	Horizontal Angulation (Minimum)	$\pm 15^\circ$
3.1.3.1.6.2	Rotation (Minimum)	$\pm 15^\circ$
	Torque Requirement (Minimum)	600,000 in. lbs.
3.1.3.1.6.3	Type:	Hydraulic actuated, direct acting, adjustable power curvable.
3.1.3.1.6.4	Opening (Minimum)	2½ inches
3.1.3.1.6.5	Positive Stop	Hydraulic lock at all positions of jaw swing range.
3.1.3.1.7	Speeds	
3.1.3.1.7.1	Positioning speed Range	0 IPM to 20 IPM
3.1.3.1.7.2	Forming Speed (full tonnage)	.2 IPM to 8 IPM
3.1.3.2	Jaws, curved (Auxiliary):	

3.1.3.2.1	Distance between jaws:	
	Maximum	300 inches
	Minimum (Horizontal)	0 inches
	Minimum (Vertical) (☉ to ☉ of jaws)	100 inches
3.1.3.2.2	Stroke, each jaw (Minimum)	90 inches
3.1.3.2.2.1	Stroke, tension cylinders (Minimum)	24 inches
3.1.3.2.3	Length of jaws, straight (Maximum)	72 inches
3.1.3.2.3.1	Curvature, minimum radius (In both directions "S" curve)	30 inches up 30 inches down
3.1.3.2.4	Tonnage (per jaw) (under repeated use)	
	Maximum	400 tons
	Minimum	100 tons or less
	Maximum (per segment)	45 tons
3.1.3.2.5	Carriage Tonnage (Per jaw) (Maximum)	2500 tons
3.1.3.2.6	Swing: Setup	Infinitely adjustable from horizontal to vertical with tangency control.
3.1.3.2.6.1	Horizontal Angulation (Minimum)	±15°
3.1.3.2.6.2	Rotation (Minimum)	±15°
	Torque Requirement (minimum)	200,000 in. lbs.
3.1.3.2.6.3	Type:	Hydraulic direct acting 56,000# per lin. inch clamping force
		Hydraulic actuated slid- ing wedge taperlock, ad- justable power curvable
3.1.3.2.6.4	Opening (Minimum)	.625 inches
3.1.3.2.6.5	Positive Stop	Hydraulic lock at all positions of jaw swing range.
3.1.3.2.7	Speeds	
3.1.3.2.7.1	Positioning speed Range	0 IPM to 20 IPM
3.1.3.2.7.2	Forming Speed (full tonnage)	.3 IPM to 8 IPM
3.1.4	Die Table	
3.1.4.1	The machine shall be designed and constructed to allow rated tonnage at rated speeds for all forming motions. Maximum tonnage shall be available at 5 IPM.	

- 3.1.4.2 Four removable die table extensions for increasing the table width to 14 feet.
- 3.1.4.3 The die table shall be provided with a forged steel die support tube to allow the maximum longitudinal - horizontal loads to the table surface with the table in the maximum up position.
- 3.1.4.4 Furnish hard chrome plated rods complete with wipers to prevent the entry of dirt and contamination into the die table cylinders.
- 3.1.4.5 The die table shall be actuated by hydraulic cylinders, micro-processor controlled.
- 3.1.4.6 At the specified tilt angle ($\pm 15^\circ$) the die table shall hold the die stationary under all loading conditions within the tonnage range of the machine.
- 3.1.4.7 The die table shall be capable of raising or lowering, both loaded and unloaded, throughout its stroke maintaining any preadjusted tilt angle.
- 3.1.4.8 Die mounting provisions along and on either side of the die table transverse centerline shall provide as follows:
 - 3.1.4.8.1 A standard 1½-inch T-slot along centerline.
 - 3.1.4.8.2 Two rows of threaded mounting holes along each edge of the table, spaced at 9-inch intervals. Each hole shall be fitted with a removable hardened insert, threaded 1"- 8 NC and fixed in place to prevent rotation. All holes shall be numbered with 1/2-inch high characters metal stamped adjacent to the holes, buyer to provide the numbering plan.
- 3.1.4.9 Four (4) pressure sensors, for control at very low tonnages, to permit "snugging" of the workpiece to the die prior to commencing the forming cycle shall be provided.
- 3.1.5 Jaws (Primary and Auxiliary)
 - 3.1.5.1 Primary jaws shall be direct acting, hydraulic actuated type with multiple cylinders. The hydraulic cylinders shall be honed to a 16 RMS finish for maximum seal life and minimum frictional resistance. Auxiliary jaws may be sliding wedge type.
 - 3.1.5.2 Controls for jaw opening and closing shall be mounted on the jaws. These controls shall be in addition to controls contained in the main control console.
 - 3.1.5.3 The primary jaws shall be designed and constructed to carry full machine tonnage over a 160-inch span at the center of the jaw length without additional or special surface preparation.
 - 3.1.5.4 Jaws shall be counter balanced about the horizontal axis of the swing with tangency control to maintain tangency of pull-off during forming. A means of maintaining a selected position and providing powered swing for set-up shall be provided, regardless of part gauge (sheet and extrusion).

- 3.1.5.5 The jaws shall be manufactured and assembled to precise tolerance to prevent oil leakage.
- 3.1.5.6 The jaws shall be segmented, power curvable type, equipped with hydraulic curving cylinders and adjustable stops to limit curvature infinitely between straight and a curvature of 80-inch radius to the primary jaws and a curvature of 30-inch radius for the auxiliary jaws. (Capable of curvature in both directions "S" curve.)
- 3.1.5.7 Jaw carriages are to be provided with wear strips on moving surfaces. The machine main rails shall be equipped to minimize friction under heavy loads. The machine main rail ways are to be hardened steel machined and polished on the bearing faces.
- 3.1.5.8 The relative movements of the jaws and table shall be such that the tension load in the workpiece is maintained at the prescribed level throughout the entire forming cycle. These movements shall effect a smooth "wrapping" of the workpiece around the die to provide a duplication of the motion experienced with a stretch-wrap press.
- 3.1.5.9 The jaws shall be individually programmable to provide independent and variable (to provide variable elongation) tension cylinder motion during the forming cycle to effect the proper wrap of the workpieces around asymmetrical dies.
- 3.1.5.10 Repositioning of jaw carriages from one keyway to another, on the main frame, shall be power positioned to the desired keyway.
- 3.1.5.11 Keys to be power assisted for disengagement and reengagement at the desired keyway.
- 3.1.6 Automatic Elongation Control
- An available device for the automatic, progressive, and positive regulation of elongation during the entire forming process through tension control, jaw movement, or a combination of the two controls.
- 3.1.7 Pre-Elongation Control
- Adjustable stroke limiting devices which allow the work pieces, regardless of variations in length, to be elongated a predetermined amount prior to the forming process.
- 3.1.8 Final Elongation
- Adjustable, automatic stroke limiting devices to allow elongation at forming cycle completion to be stopped at a predetermined point anywhere within the full stroke range of the forming device involved.
- 3.1.9 Yield Point Detector
- A device attached to the press which will sense yield of parts that can be pulled in the extrusion jaws with a minimum of a 75-ton capability, provide a visual indication of the yield condition and after the condition is attained, initiate the forming cycle.

3.1.10 Sheet Jaws

Devices with gripping surfaces in a fixed plane for holding work pieces during stretch forming process.

3.2 Control

3.2.1 The control shall be a "Computer Numerical Control" (CNC), microprocessor based system, with capacity for operating in the following modes and with the capability for separate tutorial input.

- a. Manual - Pressure form mode (see paragraph 3.2.12)
- b. Record
- c. Auto Form
- d. Memory
- e. Edit
- f. Interface Troubleshooting
- g. Self Testing (Diagnostic)
- h. Yield Point Detection

Manual Data Input Calculator (Keyboard) with full alpha numeric Cathode Ray Tube Display (CRT) shall be mounted in the control, convenient to the operator.

3.2.2 The control shall include manual, automatic (forms an entire part requiring only loading and unloading assistance from the operator) and a mode where a part is produced by entering values, and all parameters are recorded by the microprocessor in order to reproduce the same part in automatic mode.

3.2.2.1 An automatic operation shall be initiated by a single pushbutton.

3.2.3 The control shall include a means to record, on tape cassette, entire sets of commands and data to reproduce a part at a later date (playback).

3.2.3.1 The cassette tape shall be industry standard, digital quality type.

3.2.3.2 Programs on tape shall be searchable via recorded part numbers.

3.2.3.2.1 Any limitations on the alpha-numeric part number shall be noted.

3.2.3.3 A means shall be provided, such as a directory list, displayed on a CRT, of programs on a particular tape as an aid in selecting the proper tape and program.

3.2.3.4 Parameters stored on tape shall include but not be limited to pre-stretch, jaws and die table paths, post-stretch and wrap speed, etc.

3.2.3.4.1 Recorded wrap speed shall not be adjustable by the operator during production operation.

3.2.4 The control shall include an edit mode to correct or adjust stored programs and tables.

- 3.2.5 The control shall include a CRT display, mounted in a console located convenient to the operator in his normal work position and protected from damage during loading, unloading and wrapping operations.
- 3.2.5.1 The CRT shall display all stored data required for reference while wrapping a part or during setup.
- 3.2.5.2 The CRT shall display the position of the jaws, die table, and bulldozer.
- 3.2.5.3 The CRT shall display the tables of axis limits, dwells and sequencing; available through keyboard recall.
- 3.2.5.4 The CRT shall automatically display machine maintenance data such as hydraulic low level, over-temperature and dirty filter conditions, etc.
- 3.2.6 The control shall detect and perform an orderly halt at any attempt to exceed fixed or programmable axis or jaw limits.
- 3.2.7 All feedback units shall be direct driven (i.e., direct coupling , gearing, rack and pinion, etc. utilizing anti-backlash devices. If direct acting units are impractical at certain locations, cable pulls in a straight line may be proposed.
- 3.2.7.1 Feedback units shall be protected from damage during normal loading, unloading and production operation.
- 3.2.7.2 Feedback units shall be protected from entry of dust and debris.
- 3.2.7.3 Yield point detector shall incorporate force and distance measuring devices mounted on the machine. The detector shall monitor force and distance and effectively look at the stress-strain curve for each part. Yield shall be determined by detecting an offset from the straight line portion of this curve.
- 3.2.8 The control shall include an alpha numeric keyboard by which instructions for forming a part can be entered into the control system and employed by the microprocessor to produce a part in automatic mode.
- 3.2.8.1 Information entered through the keyboard must be able to be displayed on the CRT to provide the operator with reference data and instructions required to produce a part.
- 3.2.9 All operator's controls, gauges, indicators and regulating devices shall be mounted in a console and in locations compatible with good functionability and visibility.
- 3.2.9.1 All controls, gauges, switches, etc. shall be identified as to function. Identification shall be accomplished by means of engraved, stamped or etched nameplates located for maximum visibility.
- 3.2.10 The control panel shall include an "emergency stop" button to turn off hydraulic and electric power.
- 3.2.10.1 The control panel shall include an "all stop" button to stop all linear and rotary motion without the loss of memory.

- 3.2.11 The face of the CRT shall be protected by a durable plexiglass cover to prevent damage during movement of dies.
- 3.2.12 Manual mode is defined as the standard pressure forming technique of stretch forming.
- 3.2.13 The control cabinet shall operate in a 50° to 120°F, ambient temperature range and up to 95% humidity and shall be equipped with an air conditioning device.
- 3.2.14 Programmable die table and jaw carriage rates shall be capable of variable speeds to be used in the same program.
- 3.2.15 A deflection sensing device shall be located on the die table, non-tilting axis, to sense excessive deflection due to eccentric loading.
- 3.2.15.1 Upon receiving this signal, an alarm shall alert the operator and the die table force shall be reduced, to prevent damage, without changing the jaw tonnage.
- 3.3 Lubrication
 - 3.3.1 All lubrication systems shall be automatic (failsafe) and shall include all piping, hoses, fittings, ejectors, etc. to lubricate all slide ways, gearings, etc.
 - 3.3.2 Instructions regarding procedure, frequency and type of lubricant for all filler and lubrication points shall be provided.
 - 3.3 Systems which collect and reuse lubricating oils shall have oil filtering equipment which is easily changed without having to drain the reservoir. Clogged filters shall be so indicated by a signal.
 - 3.3.4 All lubrication reservoirs shall have a low level indicator.
 - 3.3.5 Suitable low lubrication pressure switches with visual devices shall be provided to alert the operator to a low pressure condition. One minute after alert of low pressure signal, the machine shall stop.
 - 3.3.6 Adequate oil reservoir capacity for at least 80 hours of continuous lubrication shall be provided.
- 3.4 Electrics
 - 3.4.1 All interconnecting wiring, cables, etc., between machine tool and control shall be furnished and be of plug-in type.
 - 3.4.2 All electrical components shall be protected from contamination and foreign matter, and from damage due to power surges, transients, power failures, etc.
 - 3.4.3 All relays rated at 120 VAC or less shall be of the sealed plug-in type.
 - 3.4.4 Arc suppressions shall be furnished for all motors, solenoids and relays to minimize noise.

- 3.4.5 All motors one-half horsepower and larger shall be dual-wound, 3-phase, have magnetic starter and 3-phase overload protection.
- 3.4.6 Control circuits shall be 120 volts or less; transformer supplied with fused, grounded secondary.
- 3.4.7 The complete system shall include protection for and not be limited to self-destruction due to overload, loss of feedback, loss of field or input phase, power supply fault, accidental motor reversal, over-temperature, shorted SCR's, etc.
- 3.4.8 The control systems shall be insensitive to any RFI or EMI either self-induced or generated by other equipment in its industrial environment. The system shall not generate RFI or EMI which may impair the operation of other equipment in its industrial environment.
- 3.4.9 Equipment shall be capable of operation from a 480 volt, 3 \emptyset , 4 wire distribution system, and shall be wired for 480 volts. Three phase motors shall be 240/480 volt wired for 480 volts.
- 3.4.10 There shall be a single point of power disconnect.
- 3.4.11 All motors, associated controls and enclosure located in the pit area shall be suitable to NEMA Standards i.e. NEMA 12 for enclosures and Totally Enclosed Fan Cooled (TEFC) for motors.

3.5 Environment/Utilities

- 3.5.1 Temperature Range 50° - 120°F.
- 3.5.2 Humidity Range 5% - 95%.
- 3.5.3 Power fluctuations - \pm 10%.
- 3.5.4 Shop Air 90 psi Max.
- 3.5.5 Water Temperature 60°F at 50 psi.

3.6 Construction

This machine shall be constructed to comply with the requirements of this specification and the codes and standards applicable to this type of equipment, NAS930 in particular.

- 3.6.1 Provide appropriate safety covers to protect all sliding and rotating surfaces, except power unit, from foreign material. Covers used shall be readily accessible and removable to allow inspection.
- 3.6.2 Rotating and sliding surfaces shall be protected by felt and/or wire reinforced rubber wipers.
- 3.6.3 Removable deck and cover plates shall be provided to cover all operational and maintenance work areas. Interior platforms shall be designed to provide various configurations as required by the machine setup. They

shall have adequate locking mechanisms to maintain platform stability. Removable handrails shall be provided for setup, maintenance and forming purposes. A minimum of three (3) sets of fill in foot walks shall be provided between the transverse platforms.

- 3.6.4 All welded steel components subject to forming load application or which directly or indirectly affect machine accuracy are stress relieved.
- 3.6.5 The machine shall be designed and constructed to allow rated tonnage and independence of control of all motions at all positions speeds, and tonnage, or any combination thereof, during the forming cycles.
- 3.6.6 Shock waves, caused by breakage of a part, shall be absorbed without damage to machine components, foundation, or operating personnel.

4.0 PAINT

- 4.1 Complete machine tool and its peripheral equipment shall be painted as follows:
 - 4.1.1 Pittsburgh Paint:
 - Item (1) - To be Determined
 - Item (2) - To be Determined
 - 4.1.2 All machines shall be painted in the following manner:
 - Tension Cylinders - Item 2
 - Die Table - Item 2
 - Electrical Panels - Item 2
 - Miscellaneous - Item 2
 - Jaw Cartridges - Item 1
 - 4.1.3 OSHA color to remain as required.
- 4.2 Reference OSHA, Section 1910.144. (OSHA Safety Colors)

5.0 RELIABILITY

- 5.1 Machine shall be operated continuously for eight hours. There shall be no failure during this run.

6.0 QUALIFICATION

- 6.1 Seller shall perform suitable measurements and tests to confirm compliance to Paragraph 3.1 and other requirements of this specification. Seller shall provide test tools, tapes and materials as applicable. In addition, Seller shall perform the following tests to prove out required capabilities of the equipment.
 - 6.1.1 Form a sheet metal skin which requires curvature of the sheet metal jaws.
 - 6.1.2 Form an extruded part requiring the use of the extrusion jaws.

- 6.1.3 Form a sheet metal part, demonstrating the stretch-draw capability requiring the use of the bulldozer.
- 6.1.4 Form a sheet metal and extruded part to demonstrate the stretch-wrap capability.
- 6.2 Buyer shall supply dies, extrusion jaw inserts and material for forming parts as required by paragraphs 6.1.1, 6.1.2, 6.1.3 and 6.1.4. The selection of these parts shall be by mutual agreement of Seller and Buyer.
- 6.3 Above tests (paragraph 6.1) shall be made by Seller with certified/verified results submitted to buyer.
- 6.3.1 Test shall include a demonstration of the press at full tonnage at Buyer's facilities.
- 6.3.1.1 Due to the size of the equipment, complete assembly and testing will be at the Buyer's facility. However, all components, subassemblies etc. will be subject to inspection and approval by customer prior to shipment to final installation site.
- 6.4 After delivery and completion of installation at the Buyer's plant, Seller's representatives will complete all acceptance tests. Final acceptance shall take place after all tests are successfully completed and full compliance to this specification has been met.

7.0 TESTS

- 7.1 All strokes, movements, other requirements and physical dimensions as specified in Paragraph 3.1 shall be checked to assure that the specified requirements are fulfilled.
- 7.2 Wrap rates shall be checked to assure that maximum and minimum rates are attained.
- 7.3 The die table, tension cylinders, jaw carriages and any other machine elements for which a maximum force is specified shall be loaded at a limit of travel through the use of appropriate dies and work pieces to assure that the rates forces are attained or exceeded.
- 7.4 The same components specified above shall be loaded to the minimum specified tonnage at the limit of travel to ascertain if machine control is available at the specified minimum tonnage.
- 7.5 Either separately or simultaneously, with above tests, the press shall be run with each component loaded to full force capacity between the limits of travel of each component. Each component shall be inspected and evaluated to determine that:
 - 7.5.1 There is no permanent visual deformation or indication of failure, impending failure, or underdesign.
 - 7.5.2 There is no deflection under full load that would affect satisfactory forming.

- 7.5.3 Operation is performed without binding, chattering, or stickiness.
- 7.5.4 Unusual sounds do not emanate from the pumping system or from structural movement of components.
- 7.5.5 No undesirable scuffing, scoring, or abrasion of bearing surfaces result from operation of the machine.
- 7.5.6 Adequate control of movement is provided.
- 7.6 A typical part shall be formed to demonstrate the capability of all phases of the control system.
- 7.6.1 For this test, the Buyer shall provide the applicable stretch form die and part material.
- 7.6.2 Parts shall be formed by different techniques to test and demonstrate the various means by which parts can be produced and means by which processing information can be introduced into the machine. This should include forming parts manually, by CNC, through keyboard inputs, by tape control, and by yield point detection of sectional parts.
- 7.6.3 The microprocess control shall be certified by a production part run of ten parts consecutively stretch wrapped with deviation of not more than .030 inch in the free state.
- 7.7 The Seller shall furnish tapes, material, and fixtures for all machine capability tests with the exception of those described in Paragraph 7.6.

8.0 ENVIRONMENT/SAFETY

- 8.1 Electrical systems or any portion thereof shall conform to NEC, NEMA and original manufacturing standards.
- 8.2 All exposed non-current carrying metal parts that may be energized under abnormal conditions shall be grounded.
- 8.3 All power transmission apparatus shall be guarded for personnel protection in accordance with "ANSI B15.1-1972".
- 8.4 Proper grounding 120 volt control circuits, protection against elements, etc., shall be provided.
- 8.5 All pinch/nip points, sharp edges/corners, hazardous moving elements, etc., shall be guarded.
- 8.6 Safety stops shall be used to limit excess travel of all axes.
- 8.7 A system shall be provided, mercury, limit excess travel of all axes.
- 8.8 Safety devices shall operate an indicator light where applicable.
- 8.9 Fail-safe design shall be employed (e.g., power failure device).

- 8.10 All components shall be Seller's latest design, affording full safety features, ease and convenience of operation and maintenance.
- 8.11 The maximum sound pressure levels measured at a distance of 6 feet from the equipment shall not exceed 85 db on the sound level meter "A" scale.
 - 8.11.1 A minimum of three sets of noise level readings shall be submitted where each set is taken at a 6 foot distance from each of the four principal orthogonal surfaces of the equipment. Each reading shall not exceed 85 db on the "A" scale.
 - 8.11.2 The test area shall be typical shop-like environment. Specifically, not an acoustically treated room.
 - 8.11.3 The tests shall be made under normal operating conditions, i.e., no load and under load.
 - 8.11.4 The individuals conducting the tests shall have proven capability in noise measurement and use approved measurement equipment and acceptable measurement procedures.
 - 8.11.5 The ambient noise level in the test area shall be less than 75 db on the "A" scale.

9.0 HYDRAULICS

- 9.1 This machine may be used on hot stretch forming operations. Its hydraulic system, i.e., hoses, filters, seals, joints, etc., shall therefore be designed for use with fire resistant hydraulic fluids approved by factory Mutual Engineering Division and Underwriters Laboratories Group 2. Specific fluids shall be as per these listed below or equivalent.

<u>Type</u>	<u>Trade Name</u>	<u>Manufacturer</u>
Phosphate Esters, Chlorinated Hydrocarbons or other synthetic fluids.	Cellulube 150, 200, 300 & 600	Celanese Corporation
	Pydraulic F9	Monsanto Chemical Company
	Arodor 1248 and 1254	Monsanto Chemical Company
	Hough to safe 1120	E. F. Houghton Company
	Shell SFR Fluid B or C	Shell Oil Company
	Pyrogard 4353 or 4355	Scony Mobile Oil Company

- 9.2 Suitable over-temperature signalling devices shall be provided to alert operator to an over-normal temperature condition and to allow shutdown of machine at end of cycle.

- 9.3 Heat exchangers shall be of stainless steel type capable of maintaining fluid temperature below the maximum operating temperature.
- 9.4 Reservoir shall be non-pressurized type.
- 9.5 Maximum hydraulic system operating pressure 5000 psi for continuous machine operation as separate and removable units.
- 9.6 All hydraulic cylinders, except jaw actuating cylinders, shall be constructed as separate and removable units.
- 9.7 Plugged "Tees" for pressure gauges shall be provided and suitably located to allow for troubleshooting.
- 9.8 Over-temperature thermal switches, alarms for each hydraulic pump shall be provided to alert the operator to an over-temperature condition and shut the system down automatically.
- 9.9 Hydraulic fluid reservoirs shall be equipped with low level alarm system, and automatic shutoff of affected pump motor.
- 9.10 The hydraulic system shall receive 100% filtration. All servo valves are to have individual filters at the input port. A bypass shall be provided for all filters.
- 9.11 Reference Paragraphs 9.7, 9.8, and 9.9 faulty indications shall be displayed on the CRT.
- 9.12 A gauge shall be conveniently located, for the operator, that indicates the level of fluid in the reservoir.
- 9.13 A fluid fill tube will be provided at floor level for ease of maintaining proper fluid level.
- 9.14 All hydraulic gauges shall indicate pressure (P.S.I.) and corresponding force (tonnage) on the face.
- 9.15 Pumps are to be sized or system shall be isolated, when satisfied and maintained, to allow the maximum pressure settings to remain constant when the maximum form rates, as specified, are required.

10.0 REQUIRED ATTACHMENTS

The following items are to be quoted as additional options, to be delivered and installed with the machine.

10.1 Extrusion Jaws

Two (2) 2500-ton extrusion jaws with 18" openings complete with adapters shall be furnished for mounting on the standard sheet jaws. The extrusion jaws and mounting adapters shall be capable of mounting on the sheet jaws without the use of special tools. Provisions shall be included for quick disconnect of extrusion jaw hydraulic lines from the main power unit of the press. Controls for opening, closing, rotation, swing, extension and retraction shall be located on the extrusion jaws.

- 10.1.1 Distance between jaws:
Minimum when fully extended 350 inches
Rotation about tension cylinder ϕ minimum $\pm 15^\circ$
- 10.1.2 Torque Requirement (Minimum) 600,000 in. lbs.

10.2 Die Table Extensions

The two following types of table extensions are desirable for various purposes. They should all be capable of supporting rated forming loads, including typically unbalanced loads which can be expected. Options should be priced by item to facilitate selection.

10.2.1 Full Width Cover

The full width cover type of extension is placed on top of the die table and consists of one continuous plate extending across width suitable gusseted and supported from underneath in overhang areas. Desired sizes are as follows: (Approximate Size)

- 10.2.1.1 Item 1: (1) each. 48" full width x 108" long
(1) each. 48" full width x 60" long
- 10.2.1.2 Item 2: (1) each. 60" full width x 108" long
(1) each. 60" full width x 60" long
- 10.2.1.3 Item 3: (1) each. 144" full width x 144" long

10.2.2 Angular Extensions

This type of extension attaches flush with the top of the die table and may support only a portion of the length of the die. Individual segments should be capable of being attached at various positions along the entire length of the die table. Segment width shall be designed to produce overall die table widths as indicated in the following items when one angular extension is mounted on each side of the die table.

- 10.2.2.1 Item 1: (4) each. Angular extension segments 6" long to produce 48" overall table width.
- 10.2.2.2 Item 2: (4) each. Angular extension segments 12" long to produce 72" overall table width.
- 10.2.2.3 Item 3: (4) each. Angular extension segments 24" long to produce 84" overall table width.

10.3 Provide a leading edge forming capability with bullnose segments.

- 10.3.1 If a strongback is required during leading edge forming at full tonnage bull nosing (400 tons per jaw), a limit switch shall be added to indicate the strongback is in place and to prevent jaw swing. When the strongback is not in place, the limit switch shall prevent locking of the jaw swing cylinder.

10.4 Vertical Bulldozer (Minimum Requirements)

10.4.1 The bulldozer shall be a four (4) post, bridged, traveling gantry type and shall have the following characteristics:

10.4.1.1 Capacity: Maximum 500 Tons

10.4.1.2 Platen Size: Length 210 Inches
Width 85 Inches

Die Mounting Hole Pattern and/or Keyway Locations shall be provided by Buyer.

10.4.1.3 Stroke: 60 Inches

10.4.1.4 Daylight: 138 Inches

(Bulldozer fully extended and die table fully retracted.)

10.4.1.5 Distance between centerline 60 inches of Jaw Trunion and Bulldozer bottom surface (Jaw horizontal and bulldozer fully extended.)

10.4.1.6 Speeds

10.4.1.6.1 Gantry travel from park position 150 I.P.M. to centerline of the die table (and back to park position).

10.4.1.6.2 Rapid advance Down (closing) - 100 I.P.M.

10.4.1.6.3 At selected forming Tonnage - 30 I.P.M. (at closing).

11.0 SHIPPING INSTRUCTIONS

11.1 Equipment shall be adequately protected from inclement weather, rust and damage during shipping. Electronic equipment shall be shipped by padded van, or equivalent.

11.2 Shipping weight and size of all cartons, crates, skids, etc. shall be furnished to Buyer's Purchasing Department prior to receipt of equipment.

11.3 The quantity of shipping units and/or crates shall appear on each unit and/or crate.

11.4 Seller shall notify Buyer's Purchasing Department of shipment 48 hours prior to arrival of equipment at site.

12.0 MANUALS/DOCUMENTATION

All data shall be furnished to the Facilities Department via the Purchasing Department. Five (5) complete sets of data shall be furnished. One set required 30 days prior to machine delivery and additional pre-installation and installation instructions and procedures. The remaining sets shall be delivered at time of shipment. Each set shall include but not be limited to the following:

12.1 Maintenance

- 12.1.1 Procedures, drawings, diagrams, schematics, etc., to maintain the mechanical, electrical, electronic, hydraulic and pneumatic mechanisms of the complete machine tool and all peripheral equipment.
- 12.1.2 Preventive maintenance procedures in Buyer's format indicating frequency schedule sample.
- 12.1.3 Complete listing of all parts by name and number, including a recommended spare parts list.
- 12.1.4 Plan and elevation views of complete system showing all necessary dimensions.
- 12.1.5 Installation and instruction data including levelling and alignment requirements, location and size of all utilities required.
- 12.1.6 "Theory of Operation" for maintenance trouble-shooting covering detailed operation of the complete system.

12.2 Operating Procedures

Procedures, drawings, illustrations to simplify operation of the machine tool and all peripheral equipment.

13.0 INSTALLATION/INSTRUCTIONS

- 13.1 Seller shall be completely responsible for the equipment installation, to include all required personnel, transportation, rigging and equipment (holddowns, pads, levelling screws, etc.) and performing all testing procedures. Buyer shall furnish all utilities and a suitable foundation. Buyer's personnel shall make all final utilities connections.

Buyer's cognizant personnel shall be notified to witness only the final test procedure.

- 13.2 Training of personnel that is not concurrent with the installation at Buyer's facility shall be defined as to where it will take place, the duration and type of training and the quantity and type of personnel required.

14.0 SELLER'S REQUIREMENTS

- 14.1 For the successful installation and checkout of the new machine.
- 14.2 Seller's personnel shall adhere to Buyer's security and fire regulations.
- 14.3 Where this specification causes a deviation from the Seller's standard product, quote the standard product in addition to the requirements specified herein.
- 14.3.1 Seller shall indicate where the standard product deviates from this specification.

- 14.3.2 Seller shall reply by item number when there is compliance/non-compliance with this specification.
- 14.4 Seller shall agree that availability of field service on a one-shift and two-shift basis in response to a service request by Buyer during the warranty period and also after its expiration shall not exceed 48-hour period.
- 14.5 Seller shall respond to each paragraph of this specification and inquiry, indicating his concurrence or not, and including a brief explanation of his intent.
- 14.6 Seller shall provide an upgraded schedule, monthly, from the start to the completion of the job.

2.4.4 BOEING SPECIFICATION NUMBER 4437 10,000-TON STRETCH PRESS

**SPECIFICATION
FOR
10,000 TON TRANSVERSE LONGITUDINAL CURVED JAW SHEET STRETCH
FORMING MACHINE, COMPUTER NUMERICALLY CONTROLLED**

Specification No. 4437
January 14, 1984

1.0 SCOPE

1.1 Purpose

This specification provides a standard for the procurement, design, installation, performance and inspection for the subject equipment. It lists minimum requirements and is not to limit design advances, safety features, ease and convenience of operation and maintenance.

1.2 Intended Use

The equipment described by this specification is to be utilized for stretch forming of ferrous and non-ferrous alloy sheets into complex contoured shapes.

2.0 CODES AND STANDARDS

Latest revisions shall apply.

- 2.1 The Joint Industrial Council (JIC) Electrical Standards, drawings only.
- 2.2 The United States of America Standards Institute (USASI).
- 2.3 The National Electrical Code (NEC).
- 2.4 National Aerospace Standard 930, Stretch Forming Machines-Airframes.
- 2.5 Occupational Safety and Health Administration (OSHA).
- 2.6 State and Local Electrical and Labor Codes.
- 2.7 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII.
- 2.8 Electronic Industries Association Standard RS-281, Numerical Control Construction Standards - Numerical Machine Tool.
- 2.9 Joint Industrial Council (JIC) Hydraulic Standards for Industrial Equipment, H-1-1973.
- 2.10 Joint Industrial Council (JIC) Pneumatic Standard for Industrial Equipment 1957.

3.0 TECHNICAL DATA

The seller shall be completely responsible for the successful design, fabrication, complete installation and testing of the machine. Seller shall provide qualified field engineering personnel to supervise the erection and installation of the machine and conduct checkout, testing and training.

3.1 Mechanical

Special design consideration shall be given to machine disassembly to permit equipment shipment by most economical method.

3.1.1 Description

3.1.1.1 NAS 930 Type I transverse and Type II longitudinal combination stretch forming machine with power curvable sheet jaws mounted in carriages transversely positionable during machine set-up and stretching operation. The die table shall be tiltable in vertical plane parallel to the sheet jaws.

3.1.1.2 The machine shall have a maximum tension tonnage of 5,000 tons per jaw for a total machine rating of 10,000 tons.

3.1.1.3 Part sizes ranging from .200 inch to 1.00 inch in thickness, 60 inches to 210 inches in width, and to 480 inches long.

3.1.2 Die Table Capacity

3.1.2.1	Size: Length Width	210 inches minimum 48 inches minimum
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3.1.2.2	Tonnage: Maximum Minimum	10,000 tons Operate under position control
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3.1.2.3	Tilt angle: Maximum : Minimum	$\pm 15^\circ$ from horizontal $\pm 10^\circ$ from horizontal
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3.1.2.4	Stroke	Approx. 144 inches
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3.1.2.4.1	Distance between centerline of jaw trunion and die table top surface. (Jaw horizontal and stroke down.)	Approx. 80 inches
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3.1.2.5	Table rotation	90°
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3.1.2.6	Speeds: Positioning Forming	0 to 15 IPM 0 to 7 IPM
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3.1.3 Jaw Capacity

3.1.3.1 Jaws, curved (Primary):

3.1.3.1.1	Distance between Jaws:	
	Maximum	480 inches
	Minimum (Horizontal)	10 inches
	Minimum (Vertical) (C to C of jaws)	144 inches, with tension cylinders fully retracted

3.1.3.1.2 Stroke, each Jaw:

Minimum, carriage cylinders	96 inches
Minimum, tension cylinders	24 inches

3.1.3.1.3	Length of Jaws, straight:	
	Maximum (effective)	210 inches
	Minimum at Maximum Tonnage	160 inches
3.1.3.1.3.1	Curvature, minimum radius	120 inches down
	Both directions ("S" curve)	480 inches up
	NOTE: 3.1.5.6	
3.1.3.1.4	Tonnage (per jaw)	
	Maximum	5,000 tons (over min. 160 inches)
	Minimum	200 tons or less
	Maximum	120 tons (per segment outboard of center 160")
	Maximum	300 tons (per segment in center 160")
3.1.3.1.5	Carriage Tonnage (per jaw) (Maximum)	5,000 tons
3.1.3.1.6	Swing: Setup	Infinitely adjustable from horizontal through vertical with tangency controls.
3.1.3.1.6.1	Horizontal Angulation (Minimum)	$\pm 15^\circ$
3.1.3.1.6.2	Rotation (Minimum)	$\pm 15^\circ$
	Torque Requirement (Minimum)	850,000 in. lbs.
3.1.3.1.6.3	Type:	Hydraulic actuated, direct acting, adjustable power curvable.
3.1.3.1.6.4	Opening (Minimum)	2½ inches
3.1.3.1.6.5	Positive Stop	Hydraulic lock at all positions of jaw swing range.
3.1.3.1.7	Speeds	
3.1.3.1.7.1	Positioning speed Range	0 IPM to 15 IPM
3.1.3.1.7.2	Forming Speed (full tonnage)	.2 IPM to 6 IPM
3.1.3.2	Jaws, curved (Auxiliary):	

- 3.1.3.2.1 Distance between jaws:
- | | |
|-------------------------------------|------------|
| Maximum | 300 inches |
| Minimum (Horizontal) | 0 inches |
| Minimum (Vertical) (C to C of jaws) | 130 inches |
- 3.1.3.2.2 Stroke, each jaw (Minimum) 90 inches
- 3.1.3.2.2.1 Stroke, tension cylinders (Minimum) 24 inches
- 3.1.3.2.3 Length of jaws, straight (Maximum) 72 inches
- 3.1.3.2.3.1 Curvature, minimum radius
(In both directions "S" curve) 30 inches
- 3.1.3.2.4 Tonnage (per jaw) (under repeated use)
- | | |
|-----------------------|------------------|
| Maximum | 400 tons |
| Minimum | 200 tons or less |
| Maximum (per segment) | 55 tons |
- 3.1.3.2.5 Carriage Tonnage (Per jaw) (Maximum) 5,000 tons
- 3.1.3.2.6 Swing: Setup Infinitely adjustable from horizontal to vertical with tangency control.
- 3.1.3.2.6.1 Horizontal Angulation (Minimum) $\pm 15^\circ$
- 3.1.3.2.6.2 Rotation (Minimum) $\pm 15^\circ$
- Torque Requirement (minimum) 200,000 in. lbs.
- 3.1.3.2.6.3 Type: Hydraulic direct acting
56,000# per lin. inch
clamping force Hydraulic actuated sliding wedge taperlock, adjustable power curvable
- 3.1.3.2.6.4 Opening (Minimum) .625 inches
- 3.1.3.2.6.5 Positive Stop Hydraulic lock at all positions of jaw swing range.
- 3.1.3.2.7 Speeds
- 3.1.3.2.7.1 Positioning speed Range 0 IPM to 15 IPM
- 3.1.3.2.7.2 Forming Speed (full tonnage) .2 IPM to 6 IPM
- 3.1.4 Die Table
- 3.1.4.1 The machine shall be designed and constructed to allow rated tonnage at rated speeds for all forming motions. Maximum tonnage shall be available at 4 IPM.

- 3.1.4.2 Four removable die table extensions for increasing the table width to 14 feet.
- 3.1.4.3 The die table shall be provided with a forged steel die support tube to allow the maximum longitudinal - horizontal loads to the table surface with the table in the maximum up position.
- 3.1.4.4 Furnish hard chrome plated rods complete with wipers to prevent the entry of dirt and contamination into the die table cylinders.
- 3.1.4.5 The die table shall be actuated by hydraulic cylinders, micro-processor controlled.
- 3.1.4.6 At the specified tilt angle ($\pm 15^\circ$) the die table shall hold the die stationary under all loading conditions within the tonnage range of the machine.
- 3.1.4.7 The die table shall be capable of raising or lowering, both loaded and unloaded, throughout its stroke maintaining any preadjusted tilt angle.
- 3.1.4.8 Die mounting provisions along and on either side of the die table transverse centerline shall provide as follows:
 - 3.1.4.8.1 A standard 1½-inch T-slot along centerline.
 - 3.1.4.8.2 Two rows of threaded mounting holes along each edge of the table, spaced at 9-inch intervals. Each hole shall be fitted with a removable hardened insert, threaded 1"- 8 NC and fixed in place to prevent rotation. All holes shall be numbered with 1/2-inch high characters metal stamped adjacent to the holes, buyer to provide the numbering plan.
- 3.1.4.9 Four (4) pressure sensors, for control at very low tonnages, to permit "snugging" of the workpiece to the die prior to commencing the forming cycle shall be provided.
- 3.1.5 Jaws (Primary and Auxiliary)
 - 3.1.5.1 All jaws shall be direct acting, hydraulic actuated type with multiple cylinders. The hydraulic cylinders shall be honed to a 16 RMS finish for maximum seal life and minimum frictional resistance.
 - 3.1.5.2 Controls for jaw opening and closing shall be mounted on the jaws. These controls shall be in addition to controls contained in the main control console.
 - 3.1.5.3 The primary jaws shall be designed and constructed to carry full machine tonnage over a 160-inch span at the center of the jaw length without additional or special surface preparation.
 - 3.1.5.4 Jaws shall be counter balanced about the horizontal axis of the swing with tangency control to maintain tangency of pull-off during forming. A means of maintaining a selected position and providing powered swing for set-up shall be provided, regardless of part gauge (sheet and extrusion).
 - 3.1.5.5 The jaws shall be manufactured and assembled to precise tolerance to prevent oil leakage.

- 3.1.5.6 The jaws shall be segmented, power curvable type, equipped with hydraulic curving cylinders and adjustable stops to limit curvature infinitely between straight and a curvature of 120-inch radius to the primary jaws and a curvature of 30-inch radius for the auxiliary jaws. (Capable of curvature in both directions "S" curve.) Design limitations of primary jaws may limit "S" curvature capability - seller to note.
- 3.1.5.7 Jaw carriages are to be provided with wear strips on moving surfaces. The machine main rails shall be equipped to minimize friction under heavy loads. The machine main rail ways are to be hardened steel machined and polished on the bearing faces.
- 3.1.5.8 The relative movements of the jaws and table shall be such that the tension load in the workpiece is maintained at the prescribed level throughout the entire forming cycle. These movements shall effect a smooth "wrapping" of the workpiece around the die to provide a duplication of the motion experienced with a stretch-wrap press.
- 3.1.5.9 The jaws shall be individually programmable to provide independent and variable (to provide variable elongation) tension cylinder motion during the forming cycle to effect the proper wrap of the workpieces around asymmetrical dies.
- 3.1.5.10 Repositioning of jaw carriages from one keyway to another, on the main frame, shall be power positioned to the desired keyway.
- 3.1.5.11 Keys to be power assisted for disengagement and reengagement at the desired keyway.
- 3.1.6 Automatic Elongation Control
- An available device for the automatic, progressive, and positive regulation of elongation during the entire forming process through tension control, jaw movement, or a combination of the two controls.
- 3.1.7 Pre-Elongation Control
- Adjustable stroke limiting devices which allow the work pieces, regardless of variations in length, to be elongated a predetermined amount prior to the forming process.
- 3.1.8 Final Elongation
- Adjustable, automatic stroke limiting devices to allow elongation at forming cycle completion to be stopped at a predetermined point anywhere within the full stroke range of the forming device involved.
- 3.1.9 Yield Point Detector
- A device attached to the press which will sense yield of parts that can be pulled in the extrusion jaws with a minimum of a 150-ton capability, provide a visual indication of the yield condition and after the condition is attained, initiate the forming cycle.

3.1.10 Sheet Jaws

Devices with gripping surfaces in a fixed plane for holding work pieces during stretch forming process.

3.2 Control

3.2.1 The control shall be a "Computer Numerical Control" (CNC), microprocessor based system, with capacity for operating in the following modes and with the capability for separate tutorial input.

- a. Manual - Pressure form mode (see paragraph 3.2.12)
- b. Record
- c. Auto Form
- d. Memory
- e. Edit
- f. Interface Troubleshooting
- g. Self Testing (Diagnostic)
- h. Yield Point Detection

Manual Data Input Calculator (Keyboard) with full alpha numeric Cathode Ray Tube Display (CRT) shall be mounted in the control, convenient to the operator.

3.2.2 The control shall include manual, automatic (forms an entire part requiring only loading and unloading assistance from the operator) and a mode where a part is produced by entering values and all parameters are recorded by the microprocessor in order to reproduce the same part in automatic mode.

3.2.2.1 An automatic operation shall be initiated by a single pushbutton.

3.2.3 The control shall include a means to record, on tape cassette, entire sets of commands and data to reproduce a part at a later date (playback).

3.2.3.1 The cassette tape shall be industry standard, digital quality type.

3.2.3.2 Programs on tape shall be searchable via recorded part numbers.

3.2.3.2.1 Any limitations on the alpha-numeric part number shall be noted.

3.2.3.3 A means shall be provided, such as a directory list, displayed on a CRT, of programs on a particular tape as an aid in selecting the proper tape and program.

3.2.3.4 Parameters stored on tape shall include but not be limited to pre-stretch, jaws and die table paths, post-stretch and wrap speed, etc.

3.2.3.4.1 Recorded wrap speed shall not be adjustable by the operator during production operation.

3.2.4 The control shall include an edit mode to correct or adjust stored programs and tables.

- 3.2.5 The control shall include a CRT display, mounted in a console located convenient to the operator in his normal work position and protected from damage during loading, unloading and wrapping operations.
- 3.2.5.1 The CRT shall display all stored data required for reference while wrapping a part or during setup.
- 3.2.5.2 The CRT shall display the position of the jaws, die table, and bulldozer.
- 3.2.5.3 The CRT shall display the tables of axis limits, dwells and sequencing; available through keyboard recall.
- 3.2.5.4 The CRT shall automatically display machine maintenance data such as hydraulic low level, over-temperature and dirty filter conditions, etc.
- 3.2.6 The control shall detect and perform an orderly halt at any attempt to exceed fixed or programmable axis or jaw limits.
- 3.2.7 All feedback units shall be direct driven (i.e., direct coupling , gearing, rack and pinion, etc.), utilizing anti-backlash devices. If direct driven units are impractical at certain locations, cable pulls in a straight line may be proposed.
- 3.2.7.1 Feedback units shall be protected from damage during normal loading, unloading and production operation.
- 3.2.7.2 Feedback units shall be protected from entry of dust and debris.
- 3.2.7.3 Yield point detector shall incorporate force and distance measuring devices mounted on the machine. The detector shall monitor force and distance and effectively look at the stress-strain curve for each part. Yield shall be determined by detecting an offset from the straight line portion of this curve.
- 3.2.8 The control shall include an alpha numeric keyboard by which instructions for forming a part can be entered into the control system and employed by the microprocessor to produce a part in automatic mode.
- 3.2.8.1 Information entered through the keyboard must be able to be displayed on the CRT to provide the operator with reference data and instructions required to produce a part.
- 3.2.9 All operator's controls, gauges, indicators and regulating devices shall be mounted in a console and in locations compatible with good functionality and visibility.
- 3.2.9.1 All controls, gauges, switches, etc. shall be identified as to function. Identification shall be accomplished by means of engraved, stamped or etched nameplates located for maximum visibility.
- 3.2.10 The control panel shall include an "emergency stop" button to turn off hydraulic and electric power.
- 3.2.10.1 The control panel shall include an "all stop" button to stop all linear and rotary motion without the loss of memory.

- 3.2.11 The face of the CRT shall be protected by a durable plexiglass cover to prevent damage during movement of dies.
- 3.2.12 Manual mode is defined as the standard pressure forming technique of stretch forming.
- 3.2.13 The control cabinet shall operate in a 50° to 120°F, ambient temperature range and up to 95% humidity and shall be equipped with an air conditioning device.
- 3.2.14 Programmable die table and jaw carriage rates shall be capable of variable speeds to be used in the same program.
- 3.2.15 A deflection sensing device shall be located on the die table, non-tilting axis, to sense excessive deflection due to eccentric loading.
- 3.2.15.1 Upon receiving this signal, an audible alarm shall alert the operator and the die table force shall be reduced, to prevent damage, without changing the jaw tonnage.

3.3 Lubrication

- 3.3.1 All lubrication systems shall be automatic (failsafe) and shall include all piping, hoses, fittings, ejectors, etc. to lubricate all slide ways, gearings, etc.
- 3.3.2 Instructions regarding procedure, frequency and type of lubricant for all filler and lubrication points shall be provided.
- 3.3 Systems which collect and reuse lubricating oils shall have oil filtering equipment which is easily changed without having to drain the reservoir. Clogged filters shall be so indicated by a signal.
- 3.3.4 All lubrication reservoirs shall have a low level indicator.
- 3.3.5 Suitable low lubrication pressure switches with visual and audible devices shall be provided to alert the operator to a low pressure condition. One minute after alert of low pressure signal, the machine shall stop.
- 3.3.6 Adequate oil reservoir capacity for at least 80 hours of continuous lubrication shall be provided.

3.4 Electrics

- 3.4.1 All interconnecting wiring, cables, etc., between machine tool and control shall be furnished and be of plug-in type.
- 3.4.2 All electrical components shall be protected from contamination and foreign matter, and from damage due to power surges, transients, power failures, etc.
- 3.4.3 All relays rated at 120 VAC or less shall be of the sealed plug-in type.
- 3.4.4 Arc suppressions shall be furnished for all motors, solenoids and relays to minimize noise.

- 3.4.5 All motors one-half horsepower and larger shall be dual-wound, 3-phase, have magnetic starter and 3-phase overload protection.
- 3.4.6 Control circuites shall be 120 volts or less; transformer supplied with fused, grounded secondary.
- 3.4.7 The complete system shall include protection for and not be limited to self-destruction due to overload, loss of feedback, loss of field or input phase, power supply fault, accidental motor reversal, over-temperature, shorted SCR's, etc.
- 3.4.8 The control systems shall be insensitive to any RFI or EMI either self-induced or generated by other equipment in its industrial environment. The system shall not generate RFI or EMI which may impair the operation of other equipment in its industrial environment.
- 3.4.9 Equipment shall be capable of operation from a 480 volt, 3 \emptyset , 4 wire distribution system, and shall be wired for 480 volts. Three phase motors shall be 240/480 volt wired for 480 volts.
- 3.4.10 There shall be a single point of power disconnect.
- 3.4.11 All motors, associated controls and enclosure located in the pit area shall be suitable to NEMA Standards i.e. NEMA 12 for enclosures and Totally Enclosed Fan Cooled (TEFC) for motors.

3.5 Environment/Utilities

- 3.5.1 Temperature Range 50° - 120°F.
- 3.5.2 Humidity Range 5% - 95%.
- 3.5.3 Power fluctuations - \pm 10%.
- 3.5.4 Shop Air 90 psi Max.
- 3.5.5 Water Temperature 60°F at 50 psi.

3.6 Construction

This machine shall be constructed to comply with the requirements of this specification and the codes and standards applicable to this type of equipment, NAS930 in particular.

- 3.6.1 Provide appropriate safety covers to protect all sliding and rotating surfaces, except power unit, from foreign material. Covers used shall be readily accessible and removable to allow inspection.
- 3.6.2 Rotating and sliding surfaces shall be protected by felt and/or wire reinforced rubber wipers.
- 3.6.3 Removable deck and cover plates shall be provided to cover all operational and maintenance work areas. Interior platforms shall be designed to provide various configurations as required by the machine setup. They

shall have adequate locking mechanisms to maintain platform stability. Removable handrails shall be provided for setup, maintenance and forming purposes. A minimum of three (3) sets of fill in foot walks shall be provided between the transverse platforms.

- 3.6.4 All welded steel components subject to forming load application or which directly or indirectly affect machine accuracy are stress relieved.
- 3.6.5 The machine shall be designed and constructed to allow rated tonnage and independence of control of all motions at all positions speeds, and tonnage, or any combination thereof, during the forming cycles.
- 3.6.6 Shock waves, caused by breakage of a part, shall be absorbed without damage to machine components, foundation, or operating personnel.

4.0 PAINT

- 4.1 Complete machine tool and its peripheral equipment shall be painted as follows:
 - 4.1.1 Pittsburgh Paint:
 - Item (1) - To be Determined
 - Item (2) - To be Determined
 - 4.1.2 All machines shall be painted in the following manner:
 - Tension Cylinders - Item 2
 - Die Table - Item 2
 - Electrical Panels - Item 2
 - Miscellaneous - Item 2
 - Jaw Cartridges - Item 1
 - 4.1.3 OSHA color to remain as required.
- 4.2 Reference OSHA, Section 1910.144. (OSHA Safety Colors)

5.0 RELIABILITY

- 5.1 Machine shall be operated continuously for eight hours. There shall be no failure during this run.

6.0 QUALIFICATION

- 6.1 Seller shall perform suitable measurements and tests to confirm compliance to Paragraph 3.1 and other requirements of this specification. Seller shall provide test tools, tapes and materials as applicable. In addition, Seller shall perform the following tests to prove out required capabilities of the equipment.
 - 6.1.1 Form a sheet metal skin which requires curvature of the sheet metal jaws.
 - 6.1.2 Form an extruded part requiring the use of the extrusion jaws.

- 6.1.3 Form a sheet metal part, demonstrating the stretch-draw capability requiring the use of the bulldozer.
- 6.1.4 Form a sheet metal and extruded part to demonstrate the stretch-wrap capability.
- 6.2 Buyer shall supply dies, extrusion jaw inserts and material for forming parts as required by paragraphs 6.1.1, 6.1.2, 6.1.3 and 6.1.4. The selection of these parts shall be by mutual agreement of Seller and Buyer.
- 6.3 Above tests (paragraph 6.1) shall be made by Seller with certified/verified results submitted to buyer.
- 6.3.1 Test shall include a demonstration of the press at full tonnage at Buyer's facilities.
- 6.3.1.1 Due to the size of the equipment, complete assembly and testing will be at the Buyer's facility. However, all components, subassemblies etc. will be subject to inspection and approval by customer prior to shipment to final installation site.
- 6.4 After delivery and completion of installation at the Buyer's plant, Seller's representatives will complete all acceptance tests. Final acceptance shall take place after all tests are successfully completed and full compliance to this specification has been met.

7.0 TESTS

- 7.1 All strokes, movements, other requirements and physical dimensions as specified in Paragraph 3.1 shall be checked to assure that the specified requirements are fulfilled.
- 7.2 Wrap rates shall be checked to assure that maximum and minimum rates are attained.
- 7.3 The die table, tension cylinders, jaw carriages and any other machine elements for which a maximum force is specified shall be loaded at a limit of travel through the use of appropriate dies and work pieces to assure that the rates forces are attained or exceeded.
- 7.4 The same components specified above shall be loaded to the minimum specified tonnage at the limit of travel to ascertain if machine control is available at the specified minimum tonnage.
- 7.5 Either separately or simultaneously, with above tests, the press shall be run with each component loaded to full force capacity between the limits of travel of each component. Each component shall be inspected and evaluated to determine that:
 - 7.5.1 There is no permanent visual deformation or indication of failure, impending failure, or underdesign.
 - 7.5.2 There is no deflection under full load that would affect satisfactory forming.

- 7.5.3 Operation is performed without binding, chattering, or stickiness.
- 7.5.4 Unusual sounds do not emanate from the pumping system or from structural movement of components.
- 7.5.5 No undesirable scuffing, scoring, or abrasion of bearing surfaces result from operation of the machine.
- 7.5.6 Adequate control of movement is provided.
- 7.6 A typical part shall be formed to demonstrate the capability of all phases of the control system.
- 7.6.1 For this test, the Buyer shall provide the applicable stretch form die and part material.
- 7.6.2 Parts shall be formed by different techniques to test and demonstrate the various means by which parts can be produced and means by which processing information can be introduced into the machine. This should include forming parts manually, by CNC, through keyboard inputs, by tape control, and by yield point detection of sectional parts.
- 7.6.3 The microprocess control shall be certified by a production part run of ten parts consecutively stretch wrapped with deviation of not more than .030 inch in the free state.
- 7.7 The Seller shall furnish tapes, material, and fixtures for all machine capability tests with the exception of those described in Paragraph 7.6.

8.0 ENVIRONMENT/SAFETY

- 8.1 Electrical systems or any portion thereof shall conform to NEC, NEMA and original manufacturing standards.
- 8.2 All exposed non-current carrying metal parts that may be energized under abnormal conditions shall be grounded.
- 8.3 All power transmission apparatus shall be guarded for personnel protection in accordance with "ANSI B15.1-1972".
- 8.4 Proper grounding 120 volt control circuits, protection against elements, etc., shall be provided.
- 8.5 All pinch/nip points, sharp edges/corners, hazardous moving elements, etc., shall be guarded.
- 8.6 Safety stops shall be used to limit excess travel of all axes.
- 8.7 A system shall be provided, mercury, limit excess travel of all axes.
- 8.8 Safety devices shall operate an indicator light where applicable.
- 8.9 Fail-safe design shall be employed (e.g., power failure device).

- 8.10 All components shall be Seller's latest design, affording full safety features, ease and convenience of operation and maintenance.
- 8.11 The maximum sound pressure levels measured at a distance of 6 feet from the equipment shall not exceed 85 db on the sound level meter "A" scale.
 - 8.11.1 A minimum of three sets of noise level readings shall be submitted where each set is taken at a 6 foot distance from each of the four principal orthogonal surfaces of the equipment. Each reading shall not exceed 85 db on the "A" scale.
 - 8.11.2 The test area shall be typical shop-like environment. Specifically, not an acoustically treated room.
 - 8.11.3 The tests shall be made under normal operating conditions, i.e., no load and under load.
 - 8.11.4 The individuals conducting the tests shall have proven capability in noise measurement and use approved measurement equipment and acceptable measurement procedures.
 - 8.11.5 The ambient noise level in the test area shall be less than 75 db on the "A" scale.

9.0 HYDRAULICS

- 9.1 This machine may be used on hot stretch forming operations. Its hydraulic system, i.e., hoses, filters, seals, joints, etc., shall therefore be designed for use with fire resistant hydraulic fluids approved by factory Mutual Engineering Division and Underwriters Laboratories Group 2. Specific fluids shall be as per these listed below or equivalent.

<u>Type</u>	<u>Trade Name</u>	<u>Manufacturer</u>
Phosphate Esters, Chlorinated Hydrocarbons or other synthetic fluids.	Cellulube 150, 200, 300 & 600	Celanese Corporation
	Pydraulic F9	Monsanto Chemical Company
	Arodor 1248 and 1254	Monsanto Chemical Company
	Houghton safe 1120	E. F. Houghton Company
	Shell SFR Fluid B or C	Shell Oil Company
	Pyrogard 4353 or 4355	Scony Mobile Oil Company

- 9.2 Suitable over-temperature signalling devices shall be provided to alert operator to an over-normal temperature condition and to allow shutdown of machine at end of cycle.

- 9.3 Heat exchangers shall be of stainless steel type capable of maintaining fluid temperature below the maximum operating temperature.
- 9.4 Reservoir shall be non-pressurized type.
- 9.5 Maximum hydraulic system operating pressure 5,000 psi for continuous machine operation as separate and removable units.
- 9.6 All hydraulic cylinders, except jaw actuating cylinders, shall be constructed as separate and removable units.
- 9.7 Plugged "Tees" for pressure gauges shall be provided and suitably located to allow for troubleshooting.
- 9.8 Over-temperature thermal switches, alarms for each hydraulic pump shall be provided to alert the operator to an over-temperature condition and shut the system down automatically.
- 9.9 Hydraulic fluid reservoirs shall be equipped with low level alarm system, and automatic shutoff of affected pump motor.
- 9.10 The hydraulic system shall receive 100% filtration. All servo valves are to have individual filters at the input port. A bypass shall be provided for all filters.
- 9.11 Reference Paragraphs 9.7, 9.8, and 9.9 faulty indications shall be displayed on the CRT.
- 9.12 A gauge shall be conveniently located, for the operator, that indicates the level of fluid in the reservoir.
- 9.13 A fluid fill tube will be provided at floor level for ease of maintaining proper fluid level.
- 9.14 All hydraulic gauges shall indicate pressure (P.S.I.) and corresponding force (tonnage) on the face.
- 9.15 Pumps are to be sized or system shall be isolated, when satisfied and maintained, to allow the maximum pressure settings to remain constant when the maximum form rates, as specified, are required.

10.0 REQUIRED ATTACHMENTS

The following items are to be quoted as additional options, to be delivered and installed with the machine.

10.1 Extrusion Jaws

Two (2) 5,000-ton extrusion jaws with 24" openings complete with adapters shall be furnished for mounting on the standard sheet jaws. The extrusion jaws and mounting adapters shall be capable of mounting on the sheet jaws without the use of special tools. Provisions shall be included for quick disconnect of extrusion jaw hydraulic lines from the main power unit of the press. Controls for opening, closing, rotation, swing, extension and retraction shall be located on the extrusion jaws.

- 10.1.1 Distance between jaws:
- | | |
|--|----------------|
| Minimum when fully extended | 320 inches |
| Rotation about tension cylinder ϕ minimum | $\pm 15^\circ$ |
- 10.1.2 Torque Requirement (Minimum) 850,000 in. lbs.

10.2 Die Table Extensions

The two following types of table extensions are desirable for various purposes. They should all be capable of supporting rated forming loads, including typically unbalanced loads which can be expected. Options should be priced by item to facilitate selection.

10.2.1 Full Width Cover

The full width cover type of extension is placed on top of the die table and consists of one continuous plate extending across width suitable gusseted and supported from underneath in overhang areas. Desired sizes are as follows: (Approximate Size)

- 10.2.1.1 Item 1: (1) each. 60" full width x 108" long
(1) each. 60" full width x 60" long
- 10.2.1.2 Item 2: (1) each. 90" full width x 108" long
(1) each. 90" full width x 60" long
- 10.2.1.3 Item 3: (1) each. 144" full width x 144" long

10.2.2 Angular Extensions

This type of extension attaches flush with the top of the die table and may support only a portion of the length of the die. Individual segments should be capable of being attached at various positions along the entire length of the die table. Segment width shall be designed to produce overall die table widths as indicated in the following items when one angular extension is mounted on each side of the die table.

- 10.2.2.1 Item 1: (4) each. Angular extension segments 12" long to produce 72" overall table width.
- 10.2.2.2 Item 2: (4) each. Angular extension segments 20" long to produce 84" overall table width.
- 10.2.2.3 Item 3: (4) each. Angular extension segments 30" long to produce 108" overall table width.

10.3 Provide a leading edge forming capability with bullnose segments.

- 10.3.1 If a strongback is required during leading edge forming at full tonnage bull nosing (650 tons per jaw), a limit switch shall be added to indicate the strongback is in place and to prevent jaw swing. When the strongback is not in place, the limit switch shall prevent locking of the jaw swing cylinder.

10.4 Vertical Bulldozer (Minimum Requirements)

10.4.1 The bulldozer shall be four post, bridged, traveling gantry type and shall have the following characteristics:

10.4.1.1 Capacity: Maximum 1,000 Tons

10.4.1.2 Platen Size: Length 210 Inches
Width 85 Inches

Die Mounting Hole Pattern and/or Keyway Locations shall be provided by Buyer.

10.4.1.3 Stroke: 96 Inches

10.4.1.4 Daylight: 144 Inches

(Bulldozer fully extended and die table fully retracted.)

10.4.1.5 Distance between centerline 48 inches of Jaw Trunion and Bulldozer bottom surface (Jaw horizontal and bulldozer fully extended.)

10.4.1.6 Speeds

10.4.1.6.1 Gantry travel from park position 150 I.P.M. to centerline of the die table (and back to park position).

10.4.1.6.2 Rapid advance Down (closing) - 100 I.P.M.

10.4.1.6.3 At selected forming Tonnage - 30 I.P.M. (at closing).

11.0 SHIPPING INSTRUCTIONS

11.1 Equipment shall be adequately protected from inclement weather, rust and damage during shipping. Electronic equipment shall be shipped by padded van, or equivalent.

11.2 Shipping weight and size of all cartons, crates, skids, etc. shall be furnished to Buyer's Purchasing Department prior to receipt of equipment.

11.3 The quantity of shipping units and/or crates shall appear on each unit and/or crate.

11.4 Seller shall notify Buyer's Purchasing Department of shipment 48 hours prior to arrival of equipment at site.

12.0 MANUALS/DOCUMENTATION

All data shall be furnished to the Facilities Department via the Purchasing Department. Five (5) complete sets of data shall be furnished. One set required 30 days prior to machine delivery and additional pre-installation and installation instructions and procedures. The remaining sets shall be delivered at time of shipment. Each set shall include but not be limited to the following:

12.1 Maintenance

- 12.1.1 Procedures, drawings, diagrams, schematics, etc., to maintain the mechanical, electrical, electronic, hydraulic and pneumatic mechanisms of the complete machine tool and all peripheral equipment.
- 12.1.2 Preventive maintenance procedures in Buyer's format indicating frequency schedule sample.
- 12.1.3 Complete listing of all parts by name and number, including a recommended spare parts list.
- 12.1.4 Plan and elevation views of complete system showing all necessary dimensions.
- 12.1.5 Installation and instruction data including levelling and alignment requirements, location and size of all utilities required.
- 12.1.6 "Theory of Operation" for maintenance trouble-shooting covering detailed operation of the complete system.

12.2 Operating Procedures

Procedures, drawings, illustrations to simplify operation of the machine tool and all peripheral equipment.

13.0 INSTALLATION/INSTRUCTIONS

- 13.1 Seller shall be completely responsible for the equipment installation, to include all required personnel, transportation, rigging and equipment (holddowns, pads, levelling screws, etc.) and performing all testing procedures. Buyer shall furnish all utilities and a suitable foundation. Buyer's personnel shall make all final utilities connections.

Buyer's cognizant personnel shall be notified to witness only the final test procedure.

- 13.2 Training of personnel that is not concurrent with the installation at Buyer's facility shall be defined as to where it will take place, the duration and type of training and the quantity and type of personnel required.

14.0 SELLER'S REQUIREMENTS

- 14.1 For the successful installation and checkout of the new machine.
- 14.2 Seller's personnel shall adhere to Buyer's security and fire regulations.
- 14.3 Where this specification causes a deviation from the Seller's standard product, quote the standard product in addition to the requirements specified herein.
- 14.3.1 Seller shall indicate where the standard product deviates from this specification.

- 14.3.2 Seller shall reply by item number when there is compliance/non-compliance with this specification.
- 14.4 Seller shall agree that availability of field service on a one-shift and two-shift basis in response to a service request by Buyer during the warranty period and also after its expiration shall not exceed 48-hour period.
- 14.5 Seller shall respond to each paragraph of this specification and inquiry, indicating his concurrence or not, and including a brief explanation of his intent.
- 14.6 Seller shall provide an upgraded schedule, monthly, from the start to the completion of the job.

APPENDIX E

**NASA STATEMENT OF WORK
(NAS8-35969/EXHIBIT A "SCOPE OF WORK" AND EXHIBIT I)**

EXHIBIT "A"
SCOPE OF WORK

Contract NAS8-35969

LARGE STRETCH PRESS FACILITY

The purpose of this study is to (1) assess and document the advantages/disadvantages of a government agency investment in a large stretch form press on the order of 5000 tons capacity (2) develop a procurement specification for the press, (3) provide trade study data that will permit an optimum site location.

INTRODUCTION

A NASA/MSFC survey indicates that an investment in a large stretch form press on the order of 5000 ton capacity (largest existing facility is 750 ton capacity) would be cost effective for several applications if implementation is made in a timely manner. The potential benefits to the Shuttle External Tank would be to stretch form dome caps, larger dome gores, and larger aft ogive gores. Stretch forming offers several potential benefits i.e. low tooling costs, quick change over, low distortion and minimal springback. Reduced manufacturing costs with improvements in component quality are projected for the dome caps now being spun formed. Fewer welds would result by forming larger gore and ogive sections.

PHASE I

TASK A

COST STUDY FOR THE SHUTTLE EXTERNAL TANK

Develop ET dome cap, gore, and ogive cost data for a projected stretch form process. Cost data shall include all costs necessary to produce the end items, i.e. cost projections for manufacturing, inspection, handling etc. Shipping costs, material costs and stretch press capitalization/depreciation cost should be omitted as parts of the ET component manufacturing cost data. Current manufacturing cost data are available for the ET dome cap (SPUN), dome gore segments and aft ogive gores which are stretch formed. Parts drawings and current cost data will be made available to the successful bidder. Anticipated manufacturing cost savings from dome gore and aft ogive gores would come from the ability to form larger parts (150% in width) than are currently used. (See Appendix 1 for projected External Tank components manufacturing rates.)

TASK B

USER SURVEY

Contact specific design/manufacturing organizations of the various government agencies and identify those agencies which have requirements (or potential) for a large stretch press

facility. Follow up with a survey form and mail to the selected government agencies. The survey questions should be constructed to establish both current needs; i.e. project hardware which is being produced by other means because large capacity stretch presses are not available, and future needs, i.e. project hardware which could be designed for stretch forming assuming a larger stretch press was available.

PHASE II

TASK A

Site Selection Trade Study

Explore the feasibility of a government owned, contractor operated Stretch forming facility conveniently located nearby applicable ancillary equipment.

Two options on site location should be provided. One option should be the optimum site recommendation to support the external tank project and the second option should be the optimum site recommendation for supporting all NASA/Government programs. (Both options may be the same site.) Site location recommendations are to be supported with sufficient cost/trade study data to substantiate the recommendations. (This is to include ancillary equipment and facilities needed to support the stretch forming press such as building size, heat treating facilities, storage and handling, inspection equipment and other metal processing equipment and facilities.)

TASK B

PRESS DESIGN REQUIREMENTS/PROCUREMENT SPECIFICATIONS

Prepare a specification for the design, procurement, installation, performance and inspection of a stretch press with a 5000 ton minimum capacity. The specification shall list minimum requirements and shall not limit design advances, safety features and convenience of operation and maintenance. The stretch press is to be utilized for stretch forming ferrous and non-ferrous alloy sheet and plate into complex contoured shapes to quality standards typical of aerospace industry. Therefore it must comply with applicable sections of NAS930 - "Stretch Forming Machines - Airframes" in addition to applicable electrical, mechanical, structural and safety codes. The press may be modular design with initially lower capacity and capability but must be capable of achieving the target 5000 ton ram force with subsequent modular additions.

A Skeleton outline of the specification (to be fully expanded) is listed below:

1. Codes and Standards
2. Responsibilities (design, fabrication, installation, test and chec

- out, training).
3. Mechanical
 - 3.1 Die table capacity and features
 - 3.2 Jaw capacity and features
 4. Elongation controls and yield point detection
 5. Lubrication features
 6. Electrical features
 7. Controls, Console (microprocessor, memory capability, etc.)
 8. Environment
 9. Utility hook up
 10. Construction
 11. Reliability, Qualification, Acceptance Test
 12. Safety
 13. Hydraulics
 14. Options
 15. Manuals, Documentation (maintenance, operating procedures)
 16. Installation, training instructions

ORIGINAL DESIGN
OF POOR QUALITY

APPENDIX I

EXTERNAL TANK STRETCH FORMED COMPONENT REQUIREMENTS

ANTICIPATED PRODUCTION RATE OF FORMED ET COMPONENTS

	YEARLY PRODUCTION RATE							
	L ₂ TANK				LH ₂ TANK			
	OGIVE GORES		DOME		FWD DOME		APT DOME	
	<u>Fwd</u>	<u>Aft</u>	<u>Gores</u>	<u>Caps</u>	<u>Gores</u>	<u>Caps</u>	<u>Gores</u>	<u>Caps</u>
Current/Yr	104	156	156	13	156	13	156	13
Mid 1987	192	288	288	24	288	24	288	24
Feb 1989	240	360	360	30	360	30	360	30
Feb 1990	320	480	480	40	480	40	480	40
Grand Total No. of each Hardware Item to be Manufactured	1800	2700	2700	225	2700	255	2700	225

SUMMARIZED TOTAL

Total No. End Caps----- 775 (Proposed en-
 Total No. Fwd Ogive Gores-----1800 larged gore
 Total No. Aft Ogive Gores (Current size---2700 sections --1800
 Total No. Dome Gores-----12 per unit)---8100 8 per unit)---5400